Request for

Site Specific Criteria

for

Point Woronzof Area of Cook Inlet

Submitted to

Alaska Department of Environmental Conservation

Submitted by

Municipality of Anchorage
Anchorage Water and Wastewater Utility

5 January 1999

Executive Summary

This document recommends and presents a request for site specific water quality criteria (SSWQC) for a portion of Knik Arm in upper Cook Inlet, Alaska. The request includes SSWQC for turbidity and a suite of heavy metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. Existing water quality standards for marine waters, which currently apply to this area, are not and can not be achieved in upper Cook Inlet for many of these constituents. Some of the metals do meet existing criteria but are included for consistency of approach, which involves using a dissolved rather than a total recoverable based criteria. This approach is based on the U.S. Environmental Protection Agency's (EPA) recently promulgated Metals Policy.

Riverine discharge to Knik Arm carries high total suspended solids (TSS) loads that originate from glacial scour of underlying rock in the watershed. Knik Arm has high tidal ranges, high tidal currents, and low biological productivity and diversity. In upper Cook Inlet, migratory, non-resident, salmon are the only commercial resource present. Because of the river loading, the effects of the extreme physical factors, and the low biological productivity, the area is unique and conditions are not consistent with the existing Alaska Water Quality Standards (AWQS). The area proposed for SSQWC is the lower portion of Knik Arm in the vicinity of Anchorage (Figure ES-1).

The rationale and justification for this request for SSWQC is based on a scientifically defensible review and analysis of existing data and information, supplemented with additional data collected in support of the request. Monitoring data from two stations in the water body, representative of locations within and distant from areas of direct anthropogenic effects are used. This data covers the period from 1991 through 1997, and in some cases through 1998. Data for the same time period characterizing the primary human discharge to the water body are used to determine the effects of human activity, which appear to be negligible. Additional samples for metals and suspended solids were collected in 1998 from the four major rivers discharging into Knik Arm. Analyses were preformed that clearly indicate that the non-dissolved fraction of metals, and the ambient levels of turbidity, are highly correlated with the TSS load from the riverine inputs, bound in mineral particles in the TSS load, and are not bioavailable.

Fish tissue analysis for both migratory salmon, the only fish from the area generally used for human consumption, and a resident species were done for mercury. The data clearly indicate that the mercury levels in the fish are below levels of concern for human health considerations, and are not related to the non-dissolved fraction of mercury in the water body. This conclusion is based on the most restrictive criteria proposed by the U. S. Food and Drug Administration (FDA) and EPA, and considers consumption rates typical of both local and nationwide populations. The data and results of the analyses are consistent with EPA's recent Cook Inlet Contaminant Study. The data indicate that the non-dissolved mercury fraction is derived from the mechanical weathering in the watershed, is bound in the mineral particles from the riverine TSS loads, and is not bioavailable.

The justification for incorporation SSWQC into the AWQS for the area under consideration include the following major points:

- The high turbidity, and high non-dissolved metals concentrations, result from upstream watershed processes and represent high natural levels of turbidity and non-bioavailable metals fractions

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- The SSWQC requested involve using natural levels of turbidity and EPA's Metals Policy of considering only the dissolved fraction of metals as potentially bioavailable and appropriate for the protection of aquatic life and associated beneficial uses of the water body

- The SSWQC for mercury considers human health risks as well as the bioavailability of the various fractions of mercury in the water body, and is protective of human health at the most restrictive levels proposed by FDA and EPA

The proposed SSWQC for turbidity is that turbidity not be elevated above natural levels. The proposed SSWQC for metals are presented in Table ES-1.

Figure ES-1
Proposed Area for Site Specific Water Quality Criteria
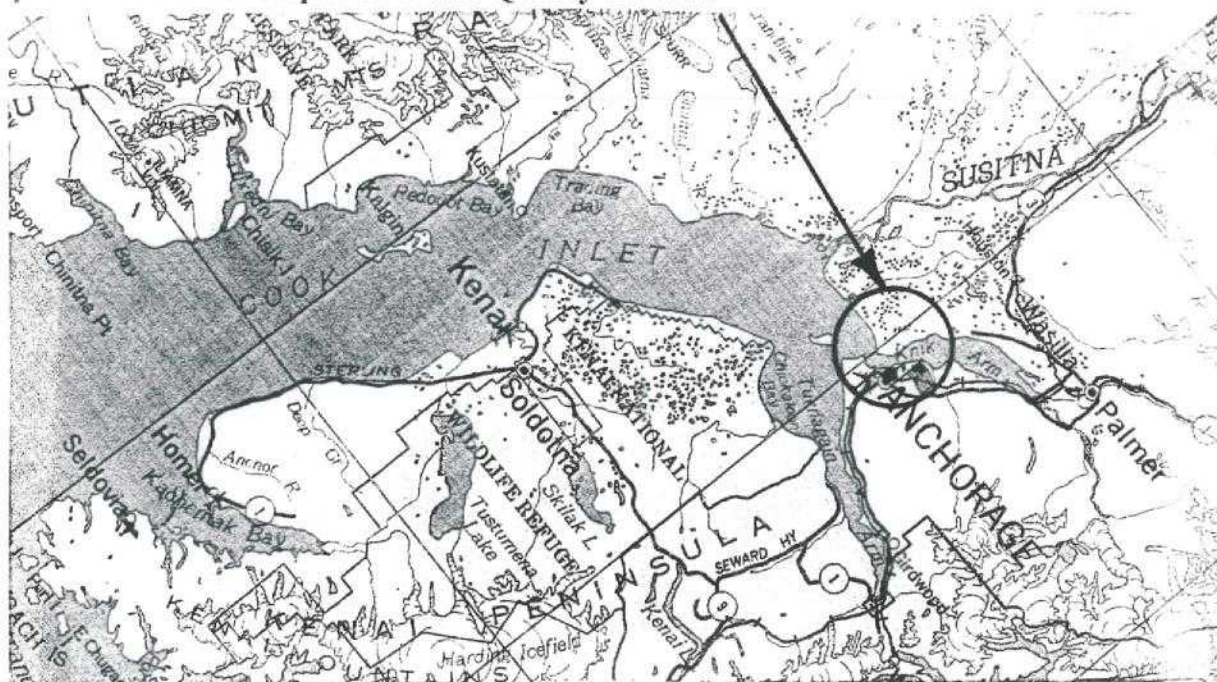
Table ES-1
Numerical criteria for metals listed. Based on the dissolved fraction. (µg/l)

Substance	Criteria Maximum Concentration (Acute)	Criteria Continuous Concentration (Chronic)
Arsenic	69	36
Cadmium	42	9.3
Chromium	1100	50
Copper	4.8	3.1
Lead	210	8.1
Mercury	1.8	0.025
Nickel	74	8.2
Selenium	290	71
Silver	1.9	-
Zinc	90	81

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1. Introduction

This document is a request for site-specific criteria for selected metals and turbidity for the waters in the vicinity of Pt. Woronzof in Cook Inlet, near Anchorage, Alaska. Site specific water quality criteria (SSWQC) are required without regard to any existing discharges, or treatment levels of such discharges, into upper Cook Inlet. The rationale and justification, on the basis of a scientifically defensible approach, is presented in this report. The purpose of the report, a brief site description, detailed descriptions of the area and substances for which SSWQC are requested, an overview of the rationale and approach, and the scope and organization of the report are included in the introductory section of the report. Subsequent sections address the sources of measured background concentrations, and discussion of justifications for the requested site specific criteria.

1.1 Purpose

The purpose of this document is to request SSWQC in the vicinity of Pt. Woronzof. The need for SSWQC has been established because the natural conditions observed in the area exceed the assimilative capacity of the water body and are inconsistent with existing criteria under the current Alaska water quality standards (AWQS). Such changes are recommended by the U.S. Environmental Protection Agency's (EPA) Metals Policy and are currently being implemented in other states.

1.2 Site Description

Knik Arm (Figure 1-1), located at the head of Cook Inlet, is part of an estuarine system with one of the largest tidal ranges in the world (30 to 39 feet [9 to 12 meters]). Knik Arm exhibits high tidal velocities (up to approximately 250 cm/sec [8.2 ft/sec]), extensive intertidal mudflats (60 percent of Knik Arm), a brackish salinity range (from 4 parts per thousand [ppt] in summer to 21 ppt in winter), and extensive ice floes from November through April. Currents and seawater density gradients are influenced primarily by the tides and secondarily by freshwater inflow, winds, and other factors.

The semidiurnal mixed tides in Knik Arm have a diurnal range of 9 meters (30 feet) and an extreme range of 12 meters (39 feet). These tides produce swift currents and vigorous mixing off of Point Woronzof. The major rivers and streams contributing fresh water directly into Knik Arm include the Matanuska River, Knik River, Eagle River, Ship Creek, and Chester Creek. Other rivers discharging into Cook Inlet below (closer to the sea) Knik Arm also are a freshwater sources to the point Woronzof area through tidal action. The Little Susitna, and rivers discharging into Turnagain Arm are the primary down inlet sources of freshwater. These sources of freshwater, combined with other rivers discharging to Cook Inlet, contribute to what little stratification occurs and keep the salinity of Knik Arm generally below 20 ppt.

The combination of local bathymetric features and large tidal amplitude creates extensive tidal flats in Knik Arm. About 60 percent of the surface area covered by high water is tidal flats at mean lower low water. Almost the entire surface area of the Arm above Point Cairn is tidal flats. In lower Knik Arm, tidal flats tend to be shore-connected and extend as much as 610 m (2,000 feet) from shore.

Net seaward exchange of water occurs at all times of the year, with the amount increasing in summer because of the increased freshwater input.

The circulation of Knik Arm is strongly influenced by the tides and bathymetry of the channel. This results in tidal currents dominating the main channel, eddy systems near shore on the flood tide, and dominating tidal currents on ebb tide. The eddies observed during the flood tide are of varying sizes and appear to be correlated with variations in flood tidal flows. Eddies occur down current of constrictions such as the narrows between Point Woronzof and Point MacKenzie. Kinnetic Laboratories has conducted an extensive annual water quality and circulation pattern monitoring program for a period of 12 years (Kinnetic Laboratories, 1987a, 1987b, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, and 1998). Circulation pattern information for Knik Arm presented here is summarized from CH2M HILL (1998).

Studies indicate very vigorous circulation in Knik Arm that periodically alternates between flood and ebb flow patterns, and with no observable seasonal variation in the overall circulation. Tidally-driven high current velocities interspersed by brief periods (15 to 20 minutes) of low-speed slack have been recorded in Knik Arm. The principal directions for flood and ebb tide flow in the vicinity of Point Woronzof are 40° and 285°, respectively (relative to true north). The principal ebb and flood directions coincide with the Knik Arm alignment near Point Woronzof, as a result of the strong influence from the local bathymetry and shoreline topography. The currents in the vicinity of Point Woronzof vary in speed from 8 cm/sec to a maximum of 250 cm/sec. The lowest 10th percentile, the 50th percentile, and the 90th percentile current speeds are 46 cm/sec, 136 cm/sec, and 195 cm/sec, respectively. Flushing characteristics of Knik Arm are summarized by CH2M HILL (1998).

1.3 Area Requested for SSWQC

The area for which site specific criteria are requested is shown in Figure 1-2. The area is defined by natural physical features, boundaries and local bathymetry, as well as consideration of the physical oceanographic processes in the area. The area extends from the constriction of Knik Arm at Point Cairn, to the northeastern end of Fire Island. The proposed boundary, as shown in Figure 1-2, extends from Cairn Point running generally south and west along the southern shoreline of Knik Arm to Point Campbell. From Point Campbell the boundary follows a straight line approximately to the northwest, across the entrance to Turnagain Arm and Knik Arm, to the northeastern end of Fire Island, and then north across the entrance to Knik Arm to the northern shoreline of upper Cook Inlet. The boundary then follows the northern shoreline generally east and north, to a point directly west of Cairn Point and then follows a straight line to the east, closing at Cairn Point. The area is therefore a relatively well defined sub-basin of upper Cook Inlet.

The area for which SSWQC are requested is based on physical processes and the unique features and environmental characteristics of the area. As described above, the tidal elevations and currents are extreme. The calculated tidal excursion of a water parcel (the distance a water parcel can be transported over a tidal half-cycle) is approximately 30 kilometers at the center of the area, based on a median tidal velocity of 136 cm/sec (CH2M HILL, 1998). Therefore, the area requested for SSWQC is less than 1/3 of a tidal excursion, and is contained well within the immediate tidal influence occurring in the vicinity.

Knik Arm and upper Cook Inlet is unique in terms of river loads as well as tidal conditions. The rivers discharging into Knik Arm, and other portions of Cook Inlet, transport large quantities of glacial outwash and associated fine sediments created by mechanical grinding of the native rock by glaciers. The riverine loads of this glacially derived sediment result in extremely high concentrations of suspended sediments and high turbidity in Knik Arm and throughout upper Cook Inlet. Since the sediments are generated by mechanical weathering from native rock, the grain size is relatively coarse compared to typical river loads in other locations. However, the high tidal currents keep the sediments in suspension.

The watersheds of Knik Arm, in which the glacial scouring occurs, are highly mineralized and therefore contain high concentrations of heavy metals associated with such geological environments. It is important to note that the metals are not in a dissolved state, and are bound within the associated mineral particles. Thus, the metals are not bioavailable. The tidal conditions, geology, and presence of glaciers create a unique situation resulting in high suspended solids and high levels of non-dissolved metals in the water body.

1.4 Substances Requested

The substances for which site-specific criteria are requested include a suite of heavy metals and turbidity. Knik Arm, and adjacent areas of Cook Inlet, have high concentrations of metals, and suspended solids with which the metals are associated, because of the unique tidal and geological conditions in the area. The turbidity and many of the metals, when expressed as total recoverable fraction, are higher than Alaska water quality criteria. Therefore, since Alaska water quality criteria (ADEC, 1997) are expressed in terms of total recoverable metals, and as a relatively low numerical limit for turbidity, there is no assimilative capacity in Knik Arm. It is noted that the dissolved fraction of metals in Knik Arm is similar to that found in typical open coastal sea water.

Because of the unique features of the area, SSWQC are required to meet AWQS and maintain consistency with the beneficial uses of the water body. The following SSWQC are requested:

- Turbidity. The proposed SSWQC for turbidity is to eliminate the quantitative limit of 25 NTU (which is well below typical background levels in Knik Arm as discussed in more detail below) and base the criterion on the protection of marine life. This essentially recognizes that the water body is naturally impaired for certain beneficial uses which the quantitative limit was intended to protect. The criteria applied for the protection of marine life states that discharge "May not reduce the depth of the compensation point ... by more than 10%" and "May not reduce the maximum secchi disk depth by more than 10%". It is proposed that these criteria be retained and the qualification that turbidity criteria be set at prevailing natural levels be required in place of the existing explicit numerical limit of 25 NTU.

- Metals (excluding mercury). It is proposed that the SSWQC for metals be based on the dissolved fraction consistent with EPA's Metals Policy (Federal Register, Vol.60, No. 86, 4 May 1995). This policy established criteria based on the dissolved fraction

for As, Cd, Cr, Cu, Pb, Ni, Se, Ag, and Zn. All of these metals have total recoverable background concentrations in upper Cook Inlet that are substantially higher than the dissolved fraction. It would not be necessary to set dissolved criteria for As, Cd, Se, and Ag to meet existing AWQS. However, it would be consistent with EPA policy, and available scientific evidence, to use the dissolved value for the entire suite of metals for which EPA has established criteria based on dissolved fraction. The use of the dissolved fraction will be discussed in more detail below.

- Mercury. Mercury is not included in the above suite of metals since the criteria for mercury is based on human health considerations, accounting for the demonstrated nature of mercury to bioaccumulate and/or bioconcentrate in the food chain. As discussed in more detail below, the available evidence shows that the non-dissolved fraction of Hg in the background waters of upper Cook Inlet is associated with particulate minerals in the suspended solids and is not bioavailable. Therefore, it is proposed that the SSWQC for Hg be based on a dissolved level calculated to be consistent with the protection of human health. This is consistent with the development of EPA Water Quality Criteria for Mercury (EPA, 1984) and the protection of human health as is discussed in detail below.

1.5 Rationale and Approach

Upper Cook Inlet has naturally high concentrations of suspended sediments and associated metals in the non-dissolved or total recoverable fraction. The material is the result of glacial melt and runoff. Discussions with EPA and ADEC have identified three methods that could be used for setting SSWQC for these substances: criteria equal to natural conditions, criteria based on water effects ratio, and criteria based on scientifically defensible rationale. Consideration of the advantages and disadvantages of each of the three methods resulted in the selection of the scientifically defensible method, with the application of prevailing natural levels to turbidity. This method can be tailored to fit the unique and extreme conditions found in upper Cook Inlet.

The approach taken in this request proposes metals criteria based on evidence that is available or can be collected regarding the toxicity of metals in Cook Inlet. The primary line of reasoning is based on EPA's metals policy which provides for the use of the dissolved fraction to set criteria. For Hg the proposed criterion is based on consideration of human health risk supported by tissue analysis of food organisms using upper Cook Inlet. For turbidity the proposed criterion recognizes that the natural level is substantially higher than the numerical value of the existing criteria and retains relative criteria that protects the receiving waters from any increase over natural levels.

Each of the three classes of substances, metals, mercury, and turbidity, are considered in detail in the sections that follow. Existing and newly collected data are used with appropriate justification to demonstrate technically sound and scientifically defensible support for the requested criteria.

1.6 Scope and Organization

With limited exceptions, this report is based on existing data previously collected for the receiving waters in upper Cook Inlet, and available information about the local oceanographic conditions. Available information on toxicity and current regulatory practices are considered and applied. Additional field data concerning the riverine loading of metals to upper Cook Inlet and fish tissue analysis for mercury were collected in support of the request for SSWQC.

Section 2 of this report presents a summary of metals and turbidity data for the input loadings and receiving waters concentrations, and present the newly collected data mentioned above. An assessment of the contribution of various sources of metals to Knik Arm is also presented in this section. Sections 3, 4, and 5 present the justifications (scientifically defensible approach) for the requested SSWQC for turbidity, metals (excluding Hg), and mercury, respectively. Sources are referenced at the end of the report. Detailed presentations of supporting data are provided in the references and Appendices I-IV.

Figure 1-1
Location Map

SITE-SPECIFIC CRITERIA AREA
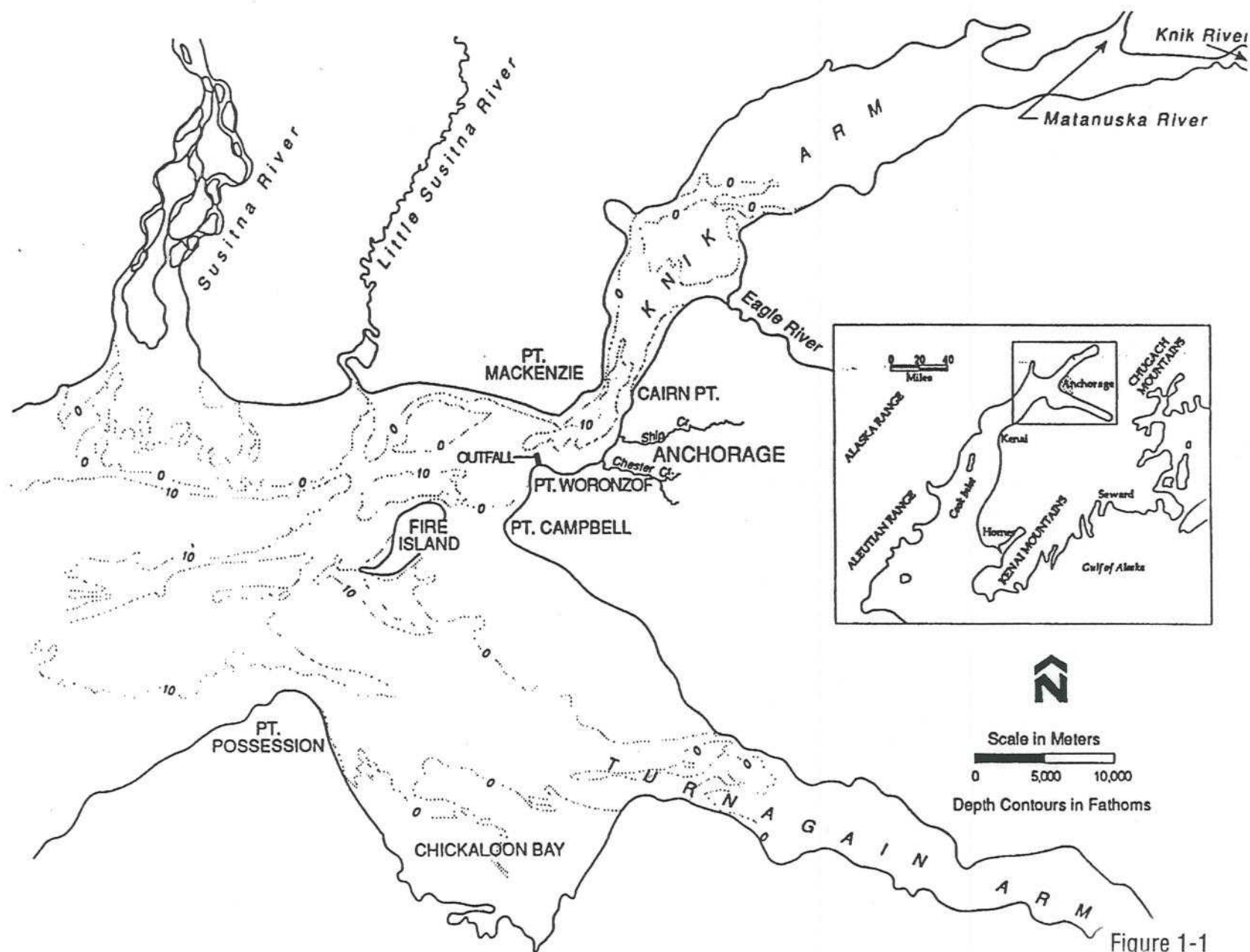
Figure 1-2
Proposed SSWQC Area

2. Sources and Background Concentrations

This section provides a description and summary of available information characterizing the levels and sources of the constituents of concern. The receiving water monitoring for these constituents is summarized. Contributions from the major anthropogenic point sources and the riverine loads into Knik Arm are considered. The sources and fate of the various metals are discussed, and a simple mass balance to characterize the effects of the major sources is presented.

2.1 Review of Receiving Water Monitoring

The annual receiving water monitoring done by Kinetic Laboratories (1992 through 1998) provides metals concentration data for two areas within the receiving water: near Point Woronzof and near Point MacKenzie. The area near Pt. Woronzof is in the immediate vicinity of the discharge from the Municipality of Anchorage wastewater treatment plant. The area near Pt. MacKenzie is considered a background station well away from any substantial direct human influence. Typical locations of the sampling points are indicated in Figure 2-1, variations in these locations are small and are documented in the monitoring reports for the various sampling points (Kinnetic Laboratories, 1992 through 1998).

In the Point Woronzof area, three drogues are released at the discharge point directly over the diffuser on both flood and ebb currents. Samples for metals analysis are collected on the first flood drogue release and at two subsequent locations following the drogue. Samples are collected along the drogue trajectory, which results in sampling within the discharge plume. In the Point MacKenzie area, three drogues are released on flood and three samples for metals analysis are collected at the start and along the first of these drogue trajectories. Turbidity samples are taken at three depths at all sampling locations, and surface TSS samples have been analyzed for the most recent three years.

The results from 1991 through 1998 are used in this section of the report. The report documenting the 1998 data has not been released, therefore some of the presentation only includes the 1991 through 1997 data. The results for the receiving water metals analysis for 1991 through 1997 at the two sampling stations are given in Tables 2-1 and 2-2, respectively. Tables 2-1 and 2-2 present the dissolved and total recoverable fractions of each of the metals listed, for all three stations in each area combined. Detailed tabulations, including results for individual stations, are provided in Appendix II. The maximum, minimum, and mean values include the detection limits for those samples that were indicated as below detection. (Note: a change in methodology in selenium analysis reduced detection limits for the 1997 samples, see Appendix II for detailed compilation, and the 95th percentile of the total recoverable column includes only those samples above detection limits.)

The receiving water monitoring includes measurement of turbidity at multiple stations (typically 2 to 4) along each plume trajectory for all of the drogue releases. The data are graphically shown in Figure 2-2 for all of the monitoring episodes for 1986 and 1989. These data sets allow seasonal comparisons, the complete data set for all 12 years is provided in CH2M HILL (1998). Turbidity in May ranged from 50 to 500 NTU, for August between 100 to 800 NTU, and for October between 200 to 950 NTU. There is little difference between the Point Woronzof area and Point Mackenzie

area measurements. The Point MacKenzie region appears, on the average, somewhat more turbid than in the vicinity of the discharge.

Table 2-1
Receiving Water Metals Concentrations near Point Woronzof

		Dissolved				Total Recoverable			
		Maximum	Minimum	Average	95th percentile	Maximum	Minimum	Average	95th percentile
Arsenic	µg/l	3.11	1.06	1.632	2.37	17.8	2.68	10.419	17.35
Cadmium	µg/l	0.074	0.024	0.048	0.070	0.990	0.040	0.239	0.810
Chromium	µg/l	0.511	0.050	0.238	0.433	91.4	3.87	36.55	88.0
Copper	µg/l	7.56	0.580	1.612	3.52	55.8	3.25	25.66	48.2
Lead	µg/l	0.114	0.006	0.029	0.089	14.28	0.436	5.78	12.6
Mercury	µg/l	0.00681	0.00005	0.000762	0.00329	0.115	0.003	0.0473	0.0864
Nickel	µg/l	1.63	0.593	0.927	1.57	47.0	1.66	19.5	40.1
Selenium	µg/l	<2.90	0.122	<1.286	0.149	<7.24	0.502	<2.785	0.830
Silver	µg/l	0.249	0.004	0.035	0.132	0.570	0.009	0.167	0.510
Zinc	µg/l	3.80	0.53	1.562	3.11	661.0	14.6	140.3	302.0

Table 2-2
Receiving Water Metals Concentrations near Point MacKenzie

		Dissolved				Total Recoverable			
		Maximum	Minimum	Average	95th percentile	Maximum	Minimum	Average	95th percentile
Arsenic	µg/l	1.98	0.98	1.423	1.875	37.8	2.83	14.9	32.4
Cadmium	µg/l	0.057	0.018	0.036	0.056	0.81	0.040	0.175	0.435
Chromium	µg/l	0.829	0.06	0.290	0.790	152.0	5.23	52.5	117.0
Copper	µg/l	0.96	0.468	0.714	0.89	70.6	5.83	26.9	54.7
Lead	µg/l	0.19	<0.003	<0.036	0.13	12.3	0.655	4.688	10.7
Mercury	µg/l	0.0103	0.000071	0.001146	0.00605	0.148	0.00802	0.06021	0.119
Nickel	µg/l	1.50	0.562	0.887	1.37	49.6	2.51	17.79	38.5
Selenium	µg/l	<2.90	0.110	<1.225	0.122	<7.24	0.168	<2.59	0.623
Silver	µg/l	0.110	0.001	0.020	0.107	0.500	0.009	0.165	0.38
Zinc	µg/l	83.7	<0.2	<4.495	2.35	1390	12.8	218.3	1240

The turbidity is generally attributable to the high suspended sediment loads from the rivers. Suspended sediment is often measured as a surrogate for turbidity. There are some available concurrent measurements of TSS and turbidity (expressed as NTU) collected and analyzed during the metals sampling discussed above. This sampling includes the 1996, 1997, and 1998 sampling episodes. The average value of TSS in the vicinity of Point Woronzof was approximately 500 mg/l. The average value at Point Makenzie stations was about 350 mg/l. The concurrent TSS and turbidity data are shown in Table 2-3. There is a strong, statistically significant, correlation between TSS and turbidity, as shown in the table, when the entire data set is considered. The correlation for each of the stations individually, particularly the Point Mackenzie station, is not as strong, but still indicates a relationship between TSS and turbidity.

Location	Date	TSS	Turbidity (NTU)			
			Surface	Mid-Depth	Bottom	Average
PTWR	1996	480	294	276	195	255
		635	352	305	300	319
		180	139	176	227	181
	1997	630	210	200	220	210
		500	210	170	240	207
		1100	290	400	400	363
	1998	390	208	427	231	289
		285	160	110	131	134
		240	96	330	270	232
	Average:	493	218	266	246	243
PTMK	1996	290	137	167	209	171
		250	150	209	250	203
		470	217	231	243	230
	1997	430	200	290	390	293
		190	70	160	340	190
		440	140	220	350	237
	1998	480	199	188	273	220
		170	201	211	370	261
		410	88	260	426	258
	Average:	348	156	215	317	229
Correlation:		r =	0.6752			0.7461
(TSS vs NTU)		Samples:	18			18
		Probability:	<0.5%			<0.5%

Table 2.3
Relationship Between TSS and Turbidity

PTWR = Point Woronzof Station
PTMK = Point Mackenzie Station
Probability is that variables (TSS and NTU) are random (uncorrelated)

2.2 Measured Stream Loadings

In August 1998, Kinnetic Laboratories collected samples from four of the rivers discharging into Knik Arm and upper Cook Inlet in the vicinity of Point Woronzof. The samples were collected upstream of tidal influence (Figure 2-3) and upstream of substantial or major human influence to the extent practicable. The rivers sampled and the locations were as follows:

- Eagle River: The sampling location was upstream of the point source inputs of the Eagle River WWTP and Highland Correctional Center. The sampling location was also upstream of most nonpoint source inputs associated with the urbanized area of Eagle River and downstream of the confluence of the north and south forks of the river. The location was immediately upstream of the Eagle River Loop Road bridge crossing (Latitude 61° 17' 48.6" N; Longitude 149° 32' 24.3" W).

- Knik River: The sampling location was upstream of all urban influences and downstream of the numerous braided channels on the upper part of the river. The location was

immediately upstream of the Old Glean Highway bridge crossing (Latitude 61° 30' 16.8" N; Longitude 149° 01' 48.6" W).

- Matanuska River: The sampling Location was upstream of any point source inputs and most urban nonpoint source inputs from Palmer. The location was at a point on the river that represented all of the major flow immediately upstream of the Old Glen Highway bridge crossing (Latitude 61° 36' 29.4" N; Longitude 149° 04' 28.0" W).

- Little Susitna River: The sampling location was downstream of most urban and industrial influences since the river flows through Houston and parallels most of the developed area between Palmer and Wasilla. The location was upstream of the small boat launch at the Little Susitna Access off of the Point Mackenzie Road (Latitude 61° 28' 14.0" N; Longitude 150° 10' 27.3" W).

The Eagle River, Knik River, and Mantanuska River all drain the watershed of Knik Arm as shown on Figure 2-4. The Little Susitna River discharges just below the mouth of Kink Arm and its watershed is also shown on Figure 2-4.

The samples collected were analyzed for total recoverable and dissolved fractions of the metals. For mercury, total mercury (all forms) and methylmercury were analyzed. The results for dissolved and total recoverable fractions are presented in summary form in Table 2-4, more detailed data compilations are provided in Appendix III. The average values in Table 2-4 are calculated using the detection limit for samples reported as not detected.

Table 2-4 Average River Water Metals Concentrations (Average of Three Samples in August 1998)									
		Dissolved				Total Recoverable			
		Eagle River	Knik River	Mantunuska River	Little Susitna River	Eagle River	Knik River	Mantunuska River	Little Susitna River
Arsenic	µg/l	0.504	0.596	0.790	0.698	3.48	7.30	12.29	2.51
Cadmium	µg/l	<0.0786	<0.0786	<0.0786	<0.0786	<0.0786	<0.0786	0.1230	<0.0786
Chromium	µg/l	<0.0930	<0.0930	0.1467	0.1407	10.1	13.7	19.1	0.779
Copper	µg/l	0.264	0.209	0.329	0.727	9.44	16.5	36.8	3.77
Lead	µg/l	0.0389	<0.0336	0.0350	0.0341	2.65	5.18	8.71	0.338
Mercury	µg/l	0.000442	0.000518	0.000574	0.001156	0.0346	0.0395	0.01995	0.00655
MeHg	µg/l	0.0000380	<0.0000344	0.0000272	0.0000999	0.0000681	0.0000449	0.000138	0.0000566
Nickel	µg/l	0.496	0.303	0.746	0.396	9.52	13.6	25.7	0.92
Selenium	µg/l	<1.02	<1.02	<1.02	<1.02	1.02	<1.02	<1.02	<1.02
Silver	µg/l	<0.260	<0.260	0.361	<0.260	0.0573	0.0728	0.1091	0.0360
Zinc	µg/l	0.495	0.497	0.457	0.235	20.7	30.4	48.7	2.60

Notes: Entries preceded by "<" indicates that all three samples were below detection
Entries in italics (*0.000*) indicates that one or two of the samples were below detection.

The data in Table 2-4 indicates that the total recoverable metals in the Little Susitna samples are substantially lower than the total recoverable in the other three rivers. This may be indicative of the

geological properties of the respective watersheds which is discussed in more detail below. The ranges and overall averages, including Little Susitna, of the input riverine concentrations are summarized in Table 2-5 below. Concurrently with the metals sampling, the river samples were analyzed for TSS with the results shown in Table 2-6.

Table 2-5 Range and Overall Average River Water Metals Concentrations		Dissolved			Total Recoverable		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Arsenic	µg/l	0.993	0.258	0.647	17.50	1.740	6.394
Cadmium	µg/l	<0.0786	<0.0786	<0.0786	0.195	<0.0786	0.090
Chromium	µg/l	0.254	<0.0930	0.118	28.80	0.433	10.91
Copper	µg/l	0.844	<0.203	0.382	68.70	2.270	16.63
Lead	µg/l	0.496	<0.0336	0.350	13.50	0.228	4.219
Mercury	µg/l	0.001620	0.000330	0.000672	0.0555	0.00375	0.002514
MeHg	µg/l	0.000169	0.0000129	0.0000500	0.000177	0.0000289	0.0000770
Nickel	µg/l	1.040	<0.225	0.479	42.10	0.604	12.42
Selenium	µg/l	<1.02	<1.02	<1.02	<1.02	1.02	1.02
Silver	µg/l	0.056	<0.026	0.029	0.169	0.032	0.069
Zinc	µg/l	0.879	0.180	0.421	77.2	1.5	25.6

Notes: Entries preceded by "<" indicates that samples were below detection
Entries in italics (0.000) indicates that some samples were below detection.

Table 2-6 River Water Sampling for Total Suspended Solids (TSS) (mg/L)				
DATE	Eagle River	Knik River	Matanuska River	Little Susitna River
17-Aug-98	190	327	1100	14
19-Aug-98	90	220	560	38
25-Aug-98	40	190	300	17
Average	107	246	653	23

2.3 Sources of Stream Loading

The river samples were collected at stations upstream of tidal influence, as mentioned above, and in areas that are generally not subjected to anthropogenic effects. The total recoverable values in the rivers are typically an order of magnitude (or more) higher than the dissolved values. The high natural loadings appear to be derived from, and associated with, the high suspended sediment loads from these rivers. The source of suspended sediments is from the mechanical weathering (abrasion) associated with glacial scour in the upstream portions of the river basins. The sediments are relatively coarse grained as described in CH2M HILL (1998) typical of mechanically weathered material. The metals are probably derived from the mineral content of the rock bodies being ground down by the glacial action. Therefore, the non-dissolved fraction of metals are incorporated in inorganic mineral particles and are not bioavailable.

Table 2-7
Locations of Known Metal in Sediments in the Knik Arm and Little Susitna Watersheds [1]

Lithologic Terrane - Watershed	Location	Host Rock	Ore-related metals and associated elements enriched in river sediments [2]	Major Activity	Notes
Peninsular - Little Susitna	Willow Creek mining district	tonalite veins, pelitic schist	As, Mo, Ag, PB, Bi, Sb, Cr, Cd	gold, silver, and mercury mining	
Peninsular -Knik Arm	Boulder Creek	talkeetna formation, granodiorite	As, Cd, Pb, Bi, Ni, Cr	placer gold mining	
Peninsular -Knik Arm	Alfred Creek	talkeetna and matanuska formations, granodiorite,	Sb, Ag, As, Zn, Bi, Cr, Cd	placer gold mining	
Peninsular -Knik Arm	Rusaw Creek, South Fork Matanuska River	plutonic, foliated metamorphic rocks	Ag, Cu, Co	gold mining	High sulfide content in rocks and sediments
Peninsular - Knik Arm	Wolverine Creek	ultramafic, plutonic, foliated metamorphic rocks,	Cu, Ni, Cr, Co	gold mining	High sulfide content in rocks and sediments
Peninsular - Knik Arm	Eklentna	ultramafic, plutonic, foliated metamorphic rocks	Cu, Pb, Cr, Ni, Cd, Co	Chromite, tin, and mercury mining	High sulfide content in rocks and sediments
Chugach - Knik Arm	Girdwood mining district	argillite, meta-sandstone, quartz diorite and felsic dikes	Cu, Pb, Zn, Sb, Ag, Au, As, Bi, Ni, Cr, Cd, Co	gold mining	
Chugach - Knik Arm	Metal Creek	valdez group, felsic intrusions	As, Sb, Pb, Cu, Zn, Cr, Ni, Cd	potential for placer mining, scheelite mining (Richter, 1967)	

(1) Data from Madden (1991)
(2) Metals indicated were reported in samples as enriched with these metals

whole of south-western Alaska has been noted as having numerous prospect locations for the mining of mercury (Bundtzen, et al., 1980), because of the extensive highly mineralized and sulfur-bearing rock deposits.

Table 2-8 shows the known mercury occurrences in rocks in both the Knik Arm and Little Susitna watersheds. The rock and sediment geochemistry analysis conducted in the two watersheds has been primarily directed towards determining the extent of precious metal ore-deposits, such as gold, silver, and platinum. In the Willow Creek mining district there are historical records of 24 mines that produced mercury in addition to gold and silver listed in the *Index to Metallic Mineral Deposits of Alaska, Compiled from Published Reports of Federal and State Agencies Through 1972* (Unpublished, no date.)   It is noted that these mines are typically very small operations and generally inactive. They are considered insignificant contributors to the sediment and metals loadings in the rivers when compared to the amounts derived by glacial scour. These mines are discussed here only to indicate the highly mineralized nature of the watershed geology. One rock geochemistry analysis from the Willow Creek mining district (Albanese, et. al, 1983) did indicate that the highest Hg concentrations are found in three major rock formations found throughout the Knik Arm and Little Susitina watersheds. Table 2-9 shows the range of Hg concentrations found in the rock formations tested. In the migmatite unit (Jmi) Hg content was found to be the highest and vary between 80 and 1350 ppb.

Other analysis conducted and results reported have been for what is termed "anomalous" levels of certain metals (As, Zn, Bi, Cu, Pb, Sb), as these metals are considered better indicators of precious metal deposits. The presence or absence of lower levels of Hg have either not been noted or Hg analysis was not conducted on the samples. On a qualitative basis the supply of heavy metals, including mercury, to Knik Arm from the local watersheds is probably best described as being highly variable with the potential for a large supply being from local rocks and sediments in the watershed. This conclusion is viable given the large variation in rock formations, the large number of intrusive rock veins and zones with high mercury content, and given the numerous location of present and past gold mining activity.

If the riverine concentrations of heavy metals, are closely associated with the sediment particles, and thus the sediment load, there should be a distinct relationship between level of TSS and the concentrations of metals. There are only three samples from each river, and grouping all four rivers together will yield only a general estimate of the relationships involved. Based on a linear regression model, there was no statistically significant correlation found between dissolved metals and TSS. However, for all of the metals, except mercury, that there were sufficient samples above detection, a highly statistically significant correlation at the 0.05 percent level was found between TSS and total recoverable concentration of the metal. For mercury the correlation was statistically significant correlation (at the 5% level) for total mercury, but there was no meaningful correlation for methyl mercury. It is noted that the result for total mercury is obtained by removing an obviously aberrant data point, which shows the lowest mercury concentration at the highest measured TSS level. The 1998 data are preliminary, and this point may be resolved. There was insufficient data to assess the relationships for cadmium or selenium. The data and results are shown in Tables 2-10(A) and (B).

Table 2-8 Locations of Known Mercury Occurrences in Rocks in the Knik Arm and Little Susitna Watersheds [1]					
Lithologic Terrane - Watershed	Location	Host Rock	Ore-related Metals and associated elements enriched in rocks[2]	Mineralogy [3]	Notes
Penisular - Little Susitna	Willow Creek mining district	tonalite veins, pelitic schist	Au,, As, Ag, Hg, Pb, Zn, Te, Cu	gold, py, aspy, cp, gn, sl, sch, te	
Penisular - Knik Arm	Wolverine Creek	ultramafic rocks	Cr, Ni, Cu, Co, Pt, Pd, Hg	chr	
Chugach - Knik Arm	Girdwood mining district	argillite, meta-sandstone, quartz diorite and felsic dikes	Au, As, Sb, Hg, Pb, Zn, Ba, Cu	aspy, gn, py, sl, cp, mo, po, gold, silver	

Notes
(1) Data from Madden (1991)
(2) Metal content of rocks from others as documented by Madden (1991)
(3) Mineral abbreviations as follows: (aspy) arsenopyrite, (az) azurite, (bar) barite, (bn) bornite,
     (calc) calcite, (cc) chalcocite, (chr) chromite, (cp) chalcopyrite, (ep) epidote, (gn) galena
     (mgt) magnetite, (ml) malachite, (mo) molybdenite, (po) pyrrhotite, (py) pyrite,
     (qz) quartz, (sb) stibnite, (sch) scheelite, (sl) sphalerite, (te) tellurides

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Table 2-9
Mercury Content of Rock Geochemistry Analysis in the Willow Creek Area[1]

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Rock Unit	Rock Types	Hg Content Range - ppb
Migmatite Unit (Jmi)	plagioclase, quartz, hornblend, biotite, marble zones, schistose amphibolite zones	80 - 1350
Gossen (Tkg)	Localized zones of schist and migmatite, orange-brown gossans, massive sulfide minerals	280 - 340
Arkose (Kar)	Graywacke, sandstone, shale	80 - 90

[1] Reconnaissance level geochemistry sampling from Albanese, et al. (1983)

Table 2-10(A)
Relationship between River Metals and TSS for Dissolved Fraction (µg/l)

River	Sample	As	Cd	Cr	Cu	Pb	Hg	MeHg	Ni	Se	Ag	Zn	TSS
Eagle River	MRS98MTL0001	0.258					0.000499	0.0000220				0.267	190
Eagle River	MRS98MTL0005	0.298			0.236		0.000496	0.0000576	0.402			0.413	90
Eagle River	MRS98MTL0009	0.955			0.354		0.000330		0.780			0.806	40
Knik River	MRS98MTL0003	0.543					0.00041		0.264			0.187	370
Knik River	MRS98MTL0007	0.600					0.00059		0.261			0.879	220
Knik River	MRS98MTL0011	0.645			0.220		0.00056		0.385			0.426	190
Little Susitna	MRS98MTL0002	0.764			0.566		0.00094	0.0000821				0.208	14
Little Susitna	MRS98MTL0006	0.579		0.236	0.844		0.00162	0.000169	0.414			0.180	38
Little Susitna	MRS98MTL0010	0.750			0.771	0.0351	0.00091	0.0000487	0.550			0.318	17
Matanuska	MRS98MTL0004	0.678			0.369		0.00041	0.0000129	0.604		0.0563	0.257	1100
Matanuska	MRS98MTL0008	0.699			0.257		0.00046		0.595			0.578	560
Matanuska	MRS98MTL0012	0.993		0.254	0.361	0.0379	0.00085		1.04			0.537	300
Number of Samples:		12	0	2	9	2	12	6	10	0	1	12	
Correlation:		0.035		1.000	-0.372	1.000	-0.413	-0.522	0.113			-0.089	
Significant at 5%:		No	?	?	No	?	No	No	No	?	?	No	

Table 2-10(B)
Relationship between River Metals and TSS for Total Recoverable Fraction (µg/l)

River	Sample	As	Cd	Cr	Cu	Pb	THg	MeHg	Ni	Se	Ag	Zn	TSS
Eagle River	MRS98MTL0001	5.59		16.9	15.4	4.33	0.0555	0.000123	15.9		0.0665	34.3	190
Eagle River	MRS98MTL0005	3.11		8.81	8.70	2.39	0.0322	0.0000468	8.38		0.0527	18.5	90
Eagle River	MRS98MTL0009	1.74		4.61	4.22	1.22	0.0161		4.28		0.0528	9.34	40
Knik River	MRS98MTL0003	10.1		17.2	22.3	7.17	0.0540	0.0000289	17.9		0.0904	39.4	370
Knik River	MRS98MTL0007	6.42		12.7	14.5	4.35	0.0333	0.0000715	12.0		0.0626	26.7	220
Knik River	MRS98MTL0011	5.38		11.2	12.7	4.02	0.0311		10.8		0.0654	25.0	190
Little Susitna	MRS98MTL0002	2.23		0.433	2.27	0.228	0.00384	0.000142	0.604		0.0398	1.50	14
Little Susitna	MRS98MTL0006	3.06		1.33	6.35	0.529	0.0115	0.000177	1.43		0.0317	4.43	38
Little Susitna	MRS98MTL0010	2.24		0.575	2.69	0.258	0.00431	0.0000955	0.723		0.0364	1.87	17
Matanuska	MRS98MTL0004	17.5	0.195	28.8	68.7	13.5	(?-0.00375)	0.000101	42.1		0.169	77.2	1100
Matanuska	MRS98MTL0008	12.0	0.0954	17.6	25.9	8.01	0.0364		21.7		0.0991	44.4	560
Matanuska	MRS98MTL0012	7.36		10.8	15.8	4.62	0.0197		13.2		0.0591	24.6	300
Number of Samples:		12	2	12	12	12	11	8	12	0	12	12	
Correlation:		0.977	1.000	0.898	0.965	0.975	0.624	-0.199	0.975		0.980	0.954	
Significant at 0.05%:		YES	?	YES	YES	YES	YES@5%	No	YES	?	YES	YES	

2.4 Assessment of Major Metals Contributions to Knik Arm

The concentrations of metals, and other constituents, in upper Cook Inlet and Knik Arm originate from three primary sources: oceanic waters introduced at the mouth of the inlet, inputs from runoff from the surrounding drainages (dominated by the riverine inputs), and anthropogenic discharges (dominated by the Point Woronzof WWTP). The oceanic contributions to the metals loadings are minor, and can be neglected when compared to the concentrations found in the area. The Point Woronzof WWTP is the largest anthropogenic point source in the area, and is approximately an order of magnitude higher in flow than other such sources. The riverine loadings, characterized by samples taken generally upstream of major human influence, provide most of the metals loadings to Knik Arm.

The most meaningful measure of the affect of the discharge of wastewater into Knik Arm through the Point Woronzof WWTP, is the long-term build up of effluent concentrations throughout the area and particularly in the immediate vicinity of the discharge. Tetra Tech (1977) employed a set of link-node numerical models, the results of which can be used to predict the ambient concentrations of effluent throughout Cook Inlet. The results of the model, run for a conservative tracer introduced at the discharge point, provide a good indication of the flushing characteristics in terms of the long-term ambient effluent concentrations or build-up in Knik Arm. The results are presented for an area of approximately 30 square miles extending from Cairn Point on the northeast to a point approximately three miles southwest of Pt. Woronzof.

The model results in terms of average, maximum, and minimum relative concentrations of a tracer are presented in Table 2-11 for the anticipated effluent discharge for the year 2005. The relative concentrations were converted to dilutions and are shown for the high runoff (fall) and low runoff (spring) periods. The average concentration is representative of the entire area. The maximum concentration (minimum dilution) is representative of the area around the outfall location and represents an area of 1.5 square miles. Whole effluent ambient concentrations in the receiving waters in the immediate vicinity of the discharge is about 0.14 percent.

Table 2-11 Background Effluent Dilution for Estimated Maximum Discharge in 2005			
	Maximum [a]	Minimum [b]	Average [c]
Low Runoff Conditions	944	701	823
High Runoff Conditions	1567	940	1254
[a] Maximum dilutions in farfield well away from discharge [b] Minimum dilutions in vicinity of discharge [c] Average dilutions throughout area considered			

Using the link-node model results, the typical salinity measured in Knik Arm, and the measured values of the various metals, the relative contribution to background from the effluent and riverine sources can be estimated (oceanic contributions are neglected, since they provide only a minor contribution). Such calculations, based on simplified mass balance approaches, provide an overall assessment of the impacts and contributions of various sources.

Table 2-12 shows the predicted contribution of the discharge of the Point Woronzof effluent to the background (Point Makenzie sampling station) values of dissolved and total recoverable metals. The calculation used the annual monitoring data (1991 through 1997) for the effluent and the control station (background) in the receiving water. The estimated effluent contribution is based on the average effluent and average background values. In general the effluent contribution is on the order of 1 to 0.01 percent of the background concentrations. The effect of the discharge appears negligible, and since this is the major anthropogenic input to the water body, the result should be extendable to all direct human discharges into Knik Arm.

The high levels of total recoverable metals appears to be a result of the riverine inputs. The 1998 river concentrations are the only recent available data. These data cannot be rigorously and directly compared to the 1991-1997 receiving water data. However, the riverine loads appear to be in the range required to account for a large fraction of the receiving water metals. The 1998 river concentrations (average for the four rivers sampled) can be compared to the range of measured background concentrations in the receiving water (1991-97). To make such a comparison the fraction of river water typically found in upper Cook Inlet must be estimated from observed salinities. Since all of the samples were taken in August, when salinities range from approximately 5 to 10 parts per thousand (ppt), the fraction of river water is approximately 80 percent of the water in Knik arm (based on 7.5 ppt with full strength sea water taken as 35 ppt). Using the above assumptions the range of river fraction of metals is shown in Table 2-12.

Table 2-12 Estimated Contributions to Background Concentrations				
Substance	Percent of Background Concentrations Accounted for by Major Anthropogenic Sources		Percent of Background Concentrations Accounted for by River Loads	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable
Arsenic	0.14	0.01	26.1 to 52.8	13.5 to ≥100
Cadmium	0.38	0.19	≥100 to ≥100	88.9 to ≥100
Chromium	0.16	0.01	11.4 to ≥100	5.7 to ≥100
Copper	3.56	0.14	31.8 to 65.3	18.8 to ≥100
Lead	1.29	0.08	≥100 to ≥100	27.4 to ≥100
Mercury	0.56	0.15	5.2 to ≥100	13.6 to ≥100
Nickel	0.16	0.01	25.5 to 68.2	20.0 to ≥100
Selenium	0.11	0.11	28.1 to ≥100	11.3 to ≥100
Silver	3.59	3.99	21.1 to ≥100	11.0 to ≥100
Zinc	0.83	0.06	0.4 to ≥100	1.5 to ≥100

It appears that the riverine loadings can easily account for most of the dissolved and all of the total recoverable metals in the receiving water with the possible exception of arsenic, copper, and nickel in the dissolved fraction. Even for these metals the riverine loading appears to account for a substantial fraction of the measured levels and the remainders are consistent with the levels typically found in open coastal oceanic environments (the other primary source). There is little doubt that the river loadings of total recoverable metals are the primary source of these substances. If only the 1998

background (Point MacKenzie) receiving water sampling is considered, the results for the riverine contributions are similar as shown in Table 2-13.

Table 2-13 Estimated Contribution(s) to Background Concentrations (1998 Monitoring Data)				
Substance	Percent of Background Concentrations Accounted for by River Loads			
	Dissolved		Total Recoverable	
Arsenic	60.9 to	65.9	70.7 to	≥100
Cadmium	≥100 to	≥100	≥100 to	≥100
Chromium	69.9 to	76.1	63.2 to	≥100
Copper	57.8 to	66.1	57.3 to	95.0
Lead	≥100 to	≥100	58.9 to	≥100
Mercury	≥100 to	≥100	≥100 to	≥100
Nickel	76.3 to	84.0	62.9 to	≥100
Selenium	[All measurements below detection]			
Silver	≥100 to	≥100	≥100 to	≥100
Zinc	30.9 to	56.3	46.7 to	76.7

If the background levels of metals are associated with riverine sediment delivery, this should be reflected in the relationship between TSS and metals concentrations. The available data were examined to investigate the relationship between metal concentrations in the background water and total suspended solids. There are only two years, 1996 and 1997, of recent receiving water sampling data that includes TSS analysis of the same samples taken for metals analysis. This is a limited number of samples. There are twelve samples for each of nine metals and six useful samples for selenium. All 1996 selenium samples were below detection, but 1997 samples were successfully run at lower detection limits. These samples are comprised of three samples in the discharge area along a plume trajectory and three samples in the control area along a plume trajectory, for each year. The individual sets of three samples are taken close together in space and time. However, TSS varies by nearly an order of magnitude for this set of samples. Therefore, if there is a strong association between the TSS and metals concentrations, it should be reflected in the data set.

Tables 2-14(A)-(C) summarize the results of the analysis. Table 2-14(A) presents dissolved metals concentrations compared to TSS. Linear correlation coefficients were calculated and are shown at the bottom of the table. In no case was the correlation found to be statistically significant (at the 95 percent level). Table 2-14B) and Table 2-14(C) present the total recoverable and non-dissolved (total recoverable minus dissolved) metals concentrations, respectively. Every metal with the exception of silver (9 of the 10 metals) display high linear correlation coefficients and the correlation is statistically significant at the 95 percent level. Some of the correlations are at or closely approach values that are highly statistically significant (at the 99.5 percent level).

Table 2-14(A)
Relationship between Receiving Water Metals and TSS - Dissolved Fraction (µg/l)

Date	Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn	TSS
1997	1F1-1SW (WITHIN ZID)	1.29	0.0739	0.261	2.92	0.114	0.0004	0.826	0.144	0.132	2.91	630
1997	1F1-2SB (ZID BOUNDARY)	1.11	0.0512	0.243	0.709	0.0187	0.0006	0.784	0.149	0.040	2.3	500
1997	1F1-3SN (NEAR FIELD)	1.11	0.042	0.257	0.605	0.012	0.0007	0.799	0.127	0.022	1.785	1100
1997	1C1-1SR (CONTROL)	1.07	0.0443	0.829	0.659	0.0192	0.0005	0.973	0.11	0.017	83.7	430
1997	1C1-2SR (CONTROL)	1.04	0.0321	0.236	0.468	0.0114	0.0004	0.562	0.122	0.020	2.35	190
1997	1C1-3SR (CONTROL)	1.08	0.0357	0.721	0.502	0.0099	0.0003	0.571	0.111	0.017	2.04	440
1996	1F1-1SW (WITHIN ZID)	1.53	0.069	0.511	3.15	0.089	0.0001	1.07		0.016	2.71	480
1996	1F1-2SB (ZID BOUNDARY)	1.21	0.067	0.433	0.983	0.019	0.0001	1.13		0.023	0.76	635
1996	1F1-3SN (NEAR FIELD)	1.19	0.069	0.396	1.4	0.015	0.0002	1.04		0.017	1.1	180
1996	1C1-1SR (CONTROL)	0.98	0.054	0.41	0.826	0.016	7E-05	1.02		0.110	0.93	290
1996	1C1-2SR (CONTROL)	1.04	0.057	0.435	0.736	0.028	0.0002	1.05		0.014	0.68	250
1996	1C1-3SR (CONTROL)	1.20	0.056	0.464	0.744	0.031	0.0007	0.997		0.021	0.51	470
Number of Samples:		12	12	12	12	12	12	12	6	12	12	
Correlation Coefficient:		0.2106	-0.0025	-0.1899	0.0888	0.1528	0.4425	-0.062	0.234	0.0625	-0.038	
Statistically Significant at 5% Level		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	

Table 2-14(B)
Relationship between Receiving Water Metals and TSS – Total Recoverable Fraction (µg/l)

Date	Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn	TSS
1997	1F1-1SW (WITHIN ZID)	9.82	0.145	23.5	29.1	7.35	0.0538	23	0.505	0.031	54.9	630
1997	1F1-2SB (ZID BOUNDARY)	9.99	0.143	24.4	26.9	6.95	0.0441	22.6	0.502	0.025	52.1	500
1997	1F1-3SN (NEAR FIELD)	17.00	0.21	39.7	48.2	12.6	0.0864	40.1	0.83	0.009	88.7	1100
1997	1C1-1SR (CONTROL)	13.50	0.183	31.5	38.3	9.83	0.0655	31.5	0.623	0.011	72.1	430
1997	1C1-2SR (CONTROL)	2.83	0.0527	5.23	5.83	1.38	0.008	5.05	0.168	0.025	12.8	190
1997	1C1-3SR (CONTROL)	7.91	0.0963	17.5	20.5	5.02	0.0321	17.1	0.394	0.009	71.6	440
1996	1F1-1SW (WITHIN ZID)	12.00	0.137	30.7	30	6.41	0.0473	24.1		0.375	59.7	480
1996	1F1-2SB (ZID BOUNDARY)	11.90	0.142	33.7	34.8	7.74	0.0513	29.7		0.069	89.2	635
1996	1F1-3SN (NEAR FIELD)	8.38	0.114	20.9	21.1	4.97	0.0275	17.2		0.063	42.5	180
1996	1C1-1SR (CONTROL)	7.47	0.087	19.9	17.1	3.65	0.0252	14.4		0.031	34.5	290
1996	1C1-2SR (CONTROL)	9.33	0.097	25.5	21.4	4.63	0.0327	18		0.380	59.7	250
1996	1C1-3SR (CONTROL)	11.00	0.109	31	25.7	5.65	0.0396	22		0.048	68.9	470
Number of Samples:		12	12	12	12	12	12	12	6	12	12	
Correlation Coefficient:		0.7963	0.7995	0.7216	0.8418	0.855	0.8769	0.8442	0.8805	-0.225	0.7231	
Statistically Significant at 5% Level		YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	

Table 2-14(C)
Relationship between Receiving Water Metals and TSS – Non-Dissolved Fraction (µg/l)
(Total Recoverable minus Dissolved)

| Date	Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn	TSS
1997	1F1-1SW (WITHIN ZID)	8.53	0.0711	23.239	26.18	7.236	0.0534	22.174	0.361	-0.101	51.99	630
1997	1F1-2SB (ZID BOUNDARY)	8.88	0.0918	24.157	26.191	6.9313	0.0435	21.816	0.353	-0.015	49.8	500
1997	1F1-3SN (NEAR FIELD)	15.90	0.168	39.443	47.595	12.588	0.0857	39.301	0.703	-0.013	86.915	1100
1997	1C1-1SR (CONTROL)	12.43	0.1387	30.671	37.641	9.8108	0.065	30.527	0.513	-0.006	-11.6	430
1997	1C1-2SR (CONTROL)	1.79	0.0206	4.994	5.362	1.3686	0.0076	4.488	0.046	0.005	10.45	190
1997	1C1-3SR (CONTROL)	6.83	0.0606	16.779	19.998	5.0101	0.0318	16.529	0.283	-0.008	69.56	440
1996	1F1-1SW (WITHIN ZID)	10.47	0.068	30.189	26.85	6.321	0.0472	23.03		0.359	56.99	480
1996	1F1-2SB (ZID BOUNDARY)	10.69	0.075	33.267	33.817	7.721	0.0512	28.57		0.046	88.44	635
1996	1F1-3SN (NEAR FIELD)	7.19	0.045	20.504	19.7	4.955	0.0273	16.16		0.046	41.4	180
1996	1C1-1SR (CONTROL)	6.49	0.033	19.49	16.274	3.634	0.0251	13.38		-0.079	33.57	290
1996	1C1-2SR (CONTROL)	8.29	0.04	25.065	20.664	4.602	0.0325	16.95		0.366	59.02	250
1996	1C1-3SR (CONTROL)	9.80	0.053	30.536	24.956	5.619	0.0389	21.003		0.027	68.39	470
Number of Samples:		12	12	12	12	12	12	12	6	12	12	
Correlation Coefficient:		0.7966	0.7982	0.7278	0.8408	0.8541	0.8761	0.8511	0.8657	-0.219	0.5739	
Statistically Significant at 5% Level		YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	

For 9 of the 10 metals, the probability of a correlation between TSS and non-dissolved metal concentrations is ≥ 95 percent. This provides strong evidence that the non-dissolved metals are directly associated with the glacial scour derived suspended sediment washed into Knik Arm by rivers. It further supports the idea that these metals are bound into mineralized particles, produced by the mechanical weathering of rock by glaciers, which is non-bioavailable.

Figures 2-6 through 2-15 summarize the metals concentrations in the major anthropogenic discharge (from the Point Woronzof WWTP), receiving water at the two monitoring stations, and the riverine contributions. These figures are constructed from the following data:

- Effluent from the WWTP: Data are from annual monitoring samples taken at the same time as the receiving water monitoring samples for 1991 through 1997. Samples analyzed below detection are included at detection limits.

- Receiving Water: Data are from annual monitoring samples for 1991 through 1997 and include three samples at both stations (Point Woronzof and Point Mackenzie) along the drogue trajectories as described in more detail above. Samples analyzed below detection are included at detection limits.

- River: Data are from the August 1998 sampling and include date from all four of the rivers sampled as described in more detail above. Samples analyzed below detection are included at detection limits.

Each figure summarizes the data for a single constituent metal. For each set of samples listed in the bullets above, each of the figures shows the range of the concentrations measured as a bar (1st and 99th percentiles for the effluent and 5th and 95th percentiles for the receiving water stations and river samples). The median (50th percentile) is indicated as short solid line across the bar. The Alaska water quality standard for total recoverable metal is shown as a solid line across the plot and the EPA metals policy limits for dissolved fraction is shown as a dotted line across the plot.
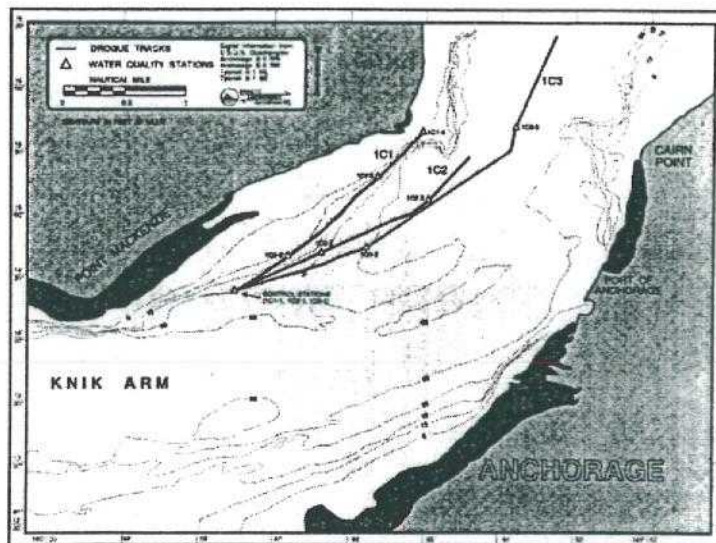
Summary of Control Drogue Tracks
and Receiving Water Sampling Locations
at Point MacKenzie, 7 August 1996.
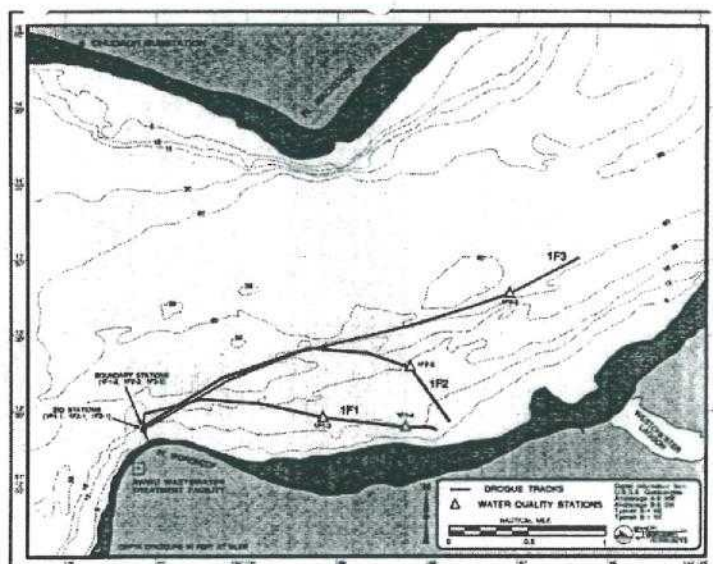
Summary of Flood Drogue Tracks
and Receiving Water Sampling Locations
at Point Woronzof, 5 August 1997.

Summary of Ebb Drogue Tracks
and Receiving Water Sampling Locations
at Point Woronzof, 5 August 1997.

Figure 2-1
**Receiving Water
Sampling Stations
for Metals and Turbidity**

Turbidity (NTU)

Point Woronzof

Turbidity (NTU)

Point Mackenzie
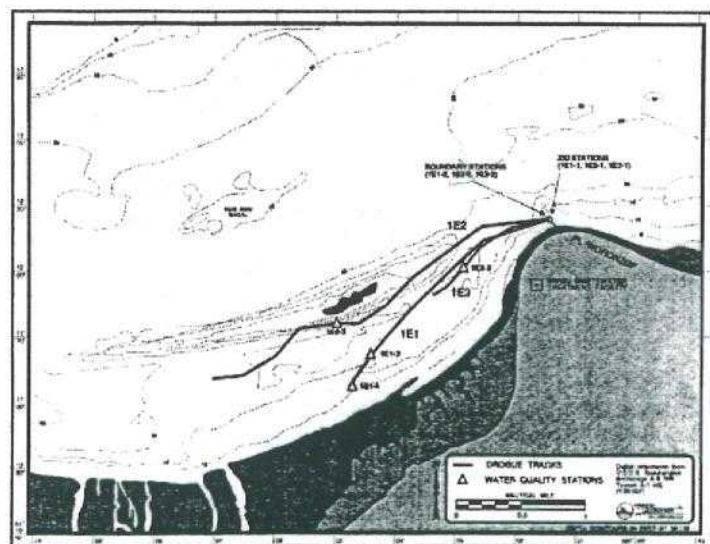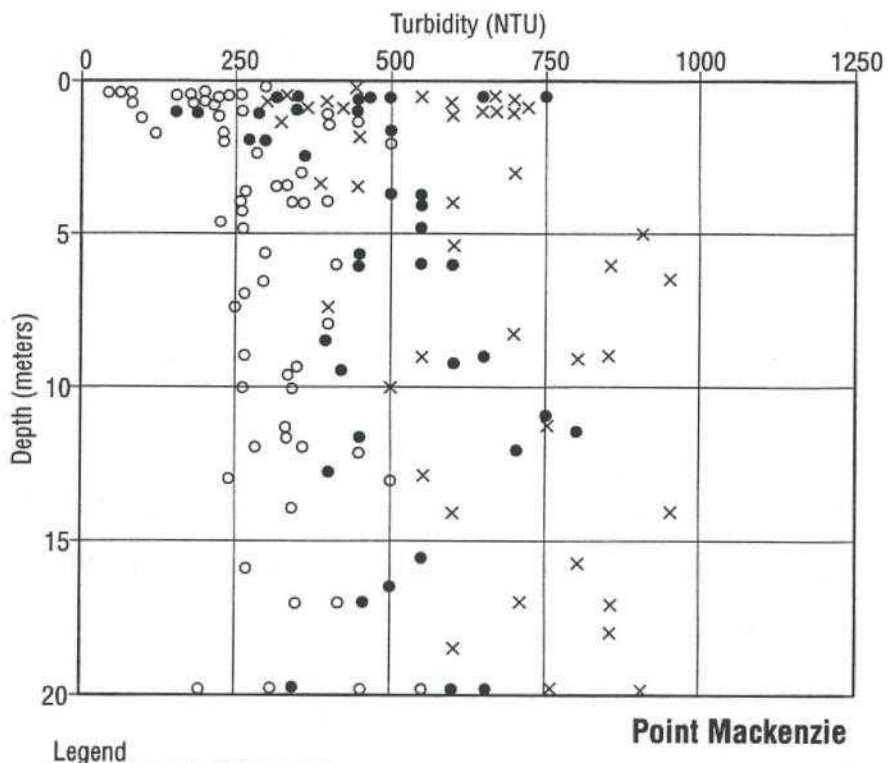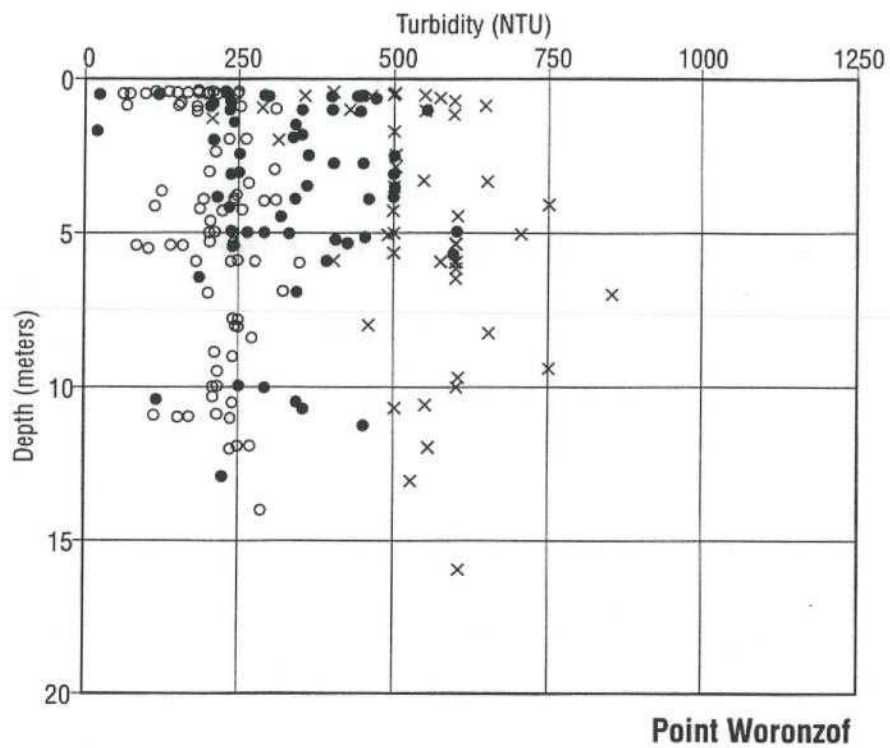
Legend

○ May '86, '89
● August '86, '89
× Sept '86, Oct '89

Figure 2-2
Receiving Water Turbidity Data

Nancy Lake

Little Susitna River

Big Lake

Cottonwood Creek

Wasilla Creek

Matanuska River

Knik River

Fish Creek

Goose Creek

KNIK ARM

Eklutna River

Peters Creek

Eklutna Lake

Eagle River

POINT MACKENZIE

Sixmile Creek

Sixmile Lake

CAIRN POINT

Ship Creek

POINT WORONZOF

ANCHORAGE

Chester Creek

N

Campbell Creek

0   5   10   15 Miles

0   5   10   15   20 Kilometers

T U R N A G A I N   A R M

Rabbit Creek

● Sample Locations

Potter Creek

Bird Creek

Figure 2-3
Approximate Location of River Water Samples

Little Susitna Watershed

Knik Arm Watershed

0   35   70
APPROXIMATE SCALE IN MILES
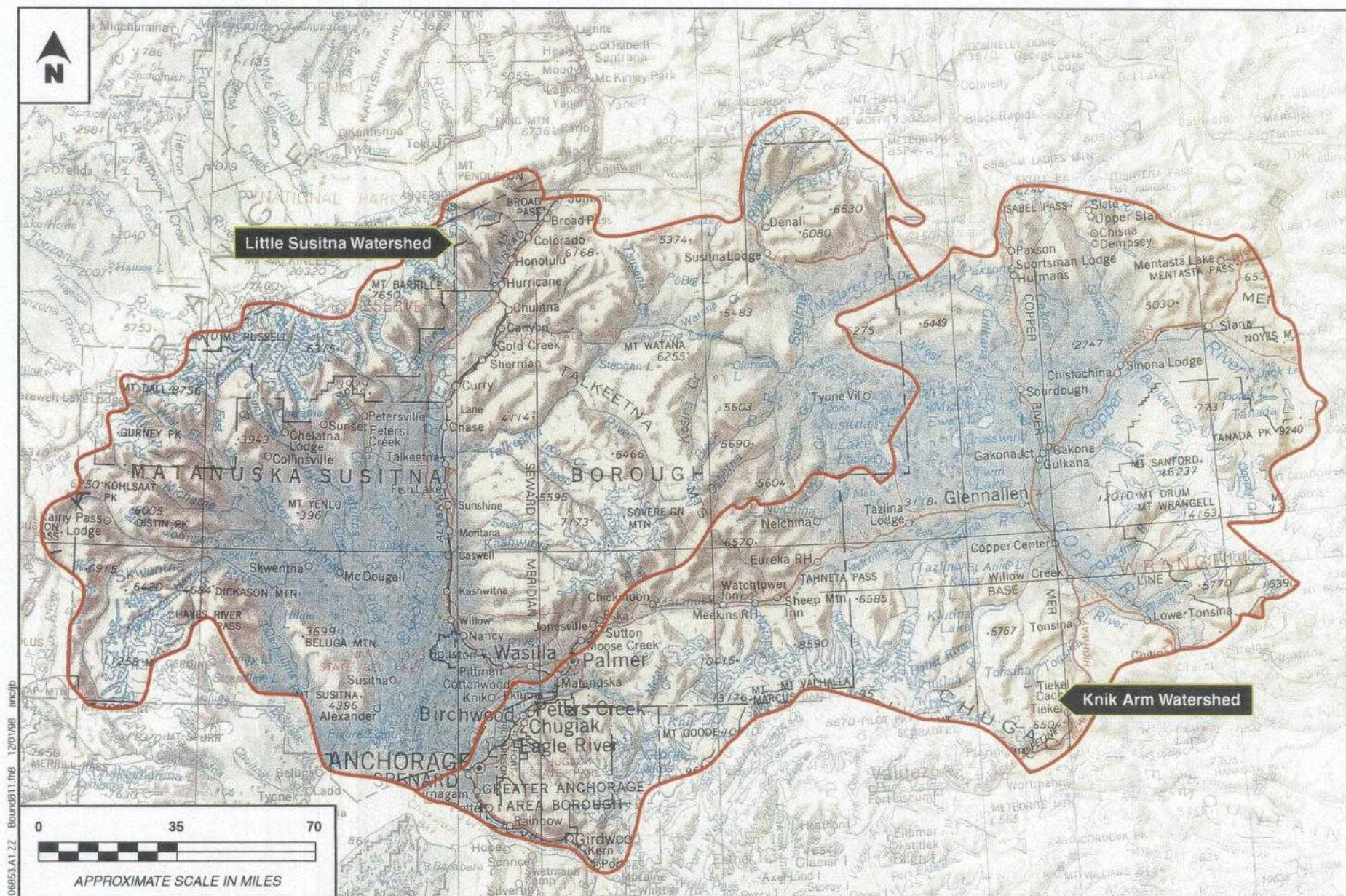
Figure 2-4

**Watershed Boundaries for
Knik Arm and Little Susitna River, Alaska**

LEGEND

- Metal province (Major and minor commodities designated)
- Mineralized area – occurrence of minerals rated high
- Intensive mining claim activity area
- Moderate to low mining claim activity area
- Lode deposit, prospect, or mine
- Placer deposit, prospect, or mine

Little Susitna Watershed

Knik Arm Watershed

Notes:
1) Blank areas on figure are from data missing on source maps.
2) Original map projection not scalable in this reduced format.

Source: *Figure 91a Metallic Minerals, Cook Inlet Subregion* and *Figure 96a Metallic Minerals, Copper River - Gulf of Alaska Subregion* U.S. Geological Survey

Figure 2-5

Metallic Minerals in Upper Cook Inlet Watersheds

ARSENIC
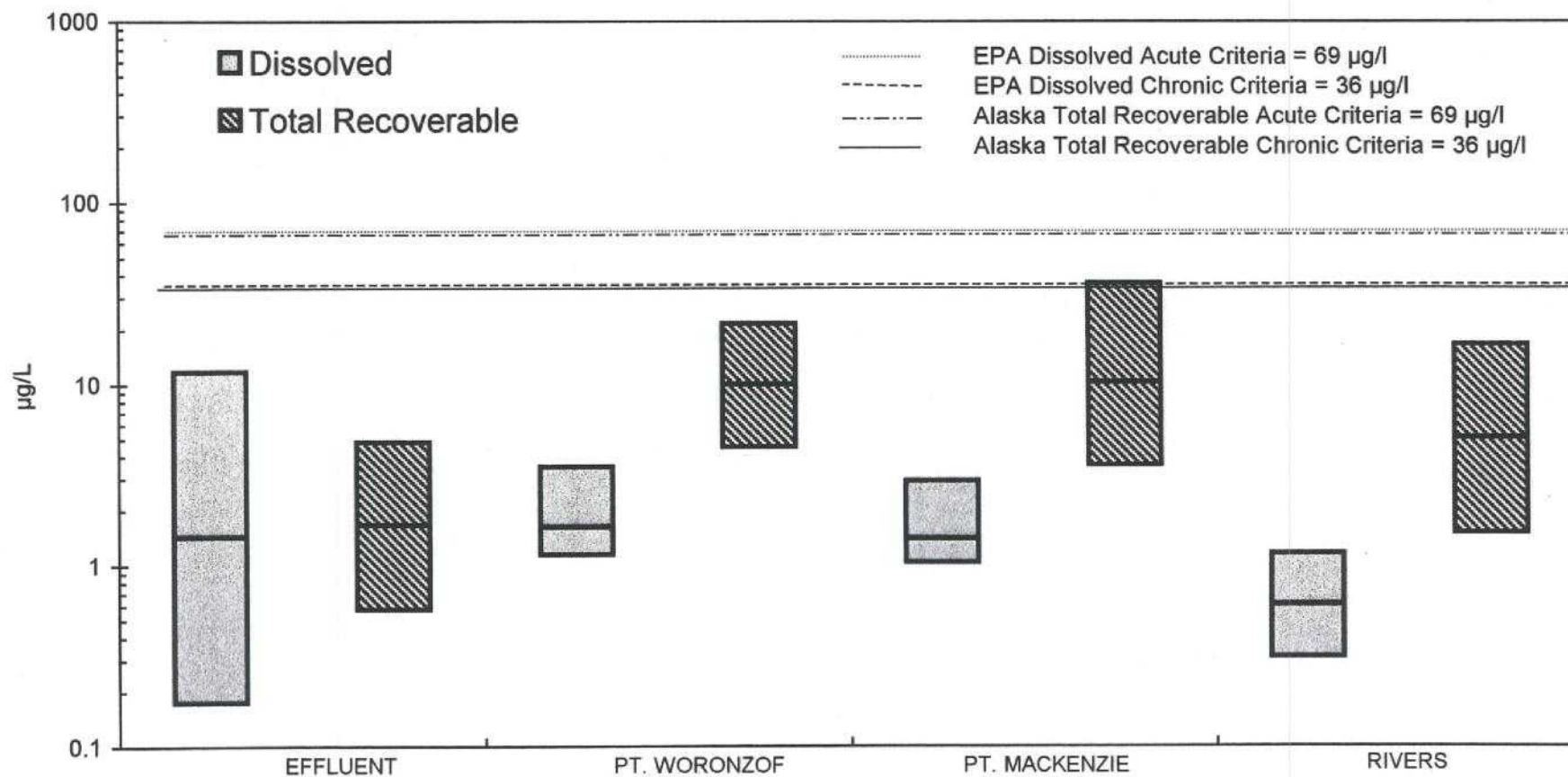
Note:
Limits are 1st to 99th Percentile for Effluent and 5th to
95th Percentile for Pt. Woronzof, Pt. MacKenzie, and
Rivers with the 50th Percentile Indicated. (Rivers and
Effluent based on Log-Normal Distribution; receiving
water stations based on sample population.)

Figure 2-6

Concentrations of Dissolved and Total Recoverable Arsenic.

CADMIUM

Figure 2-7

Concentrations of Dissolved and Total Recoverable Cadmium.

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)

CHROMIUM

Figure 2-8

Concentrations of Dissolved and Total Recoverable Chromium.

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)

COPPER

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to
95th Percentile for Pt. Woronzof, Pt. MacKenzie, and
Rivers with the 50th Percentile Indicated. (Rivers and
Effluent based on Log-Normal Distribution; receiving
water stations based on sample population.)

Figure 2-9

Concentrations of Dissolved and Total Recoverable Copper.

LEAD

Figure 2-10
Concentrations of Dissolved and Total Recoverable Lead.

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)
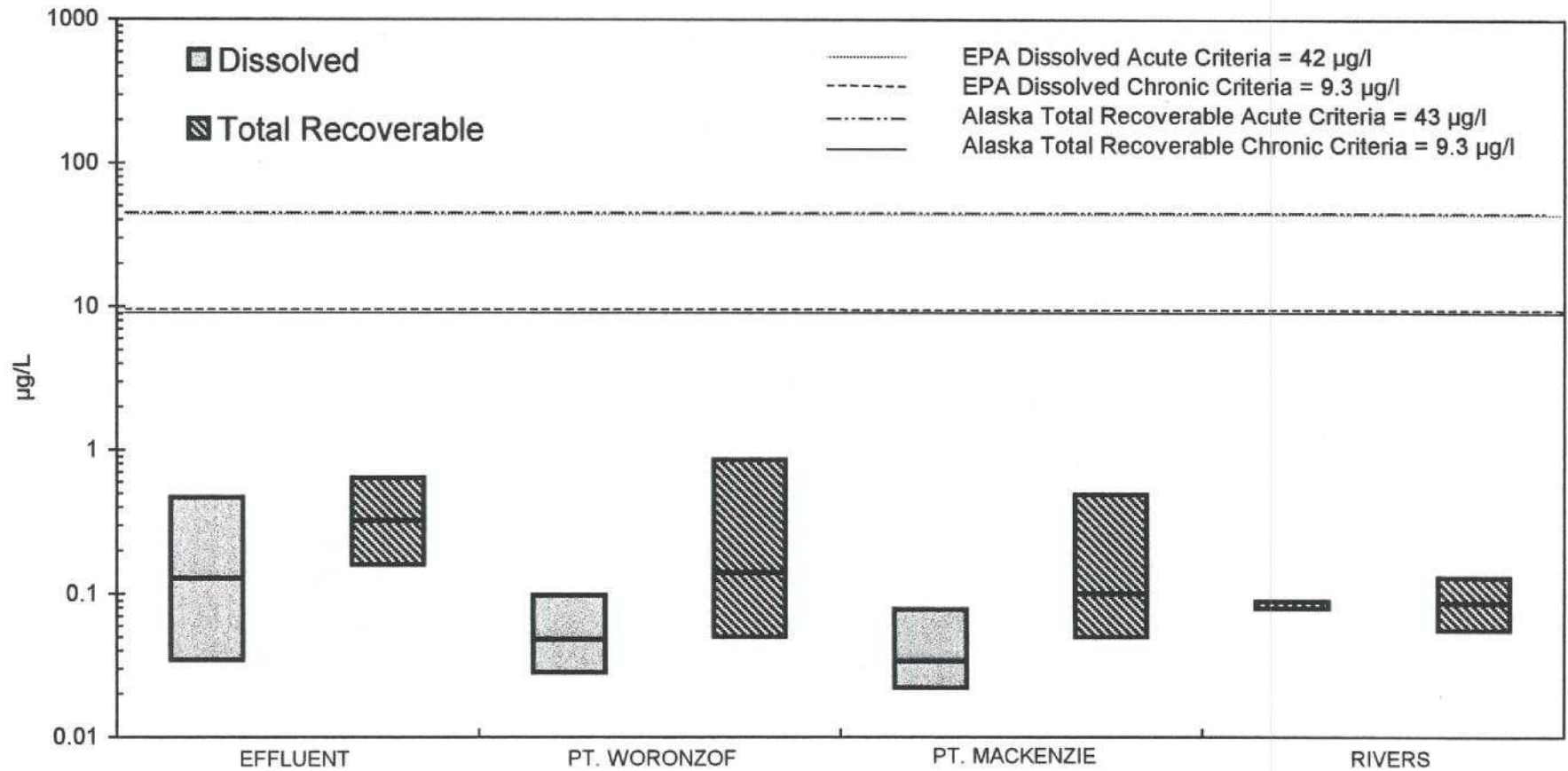
MERCURY

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)

Figure 2-11
Concentrations of Dissolved and Total Recoverable Mercury.

NICKEL

Figure 2-12

Concentrations of Dissolved and Total Recoverable Nickel.

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)
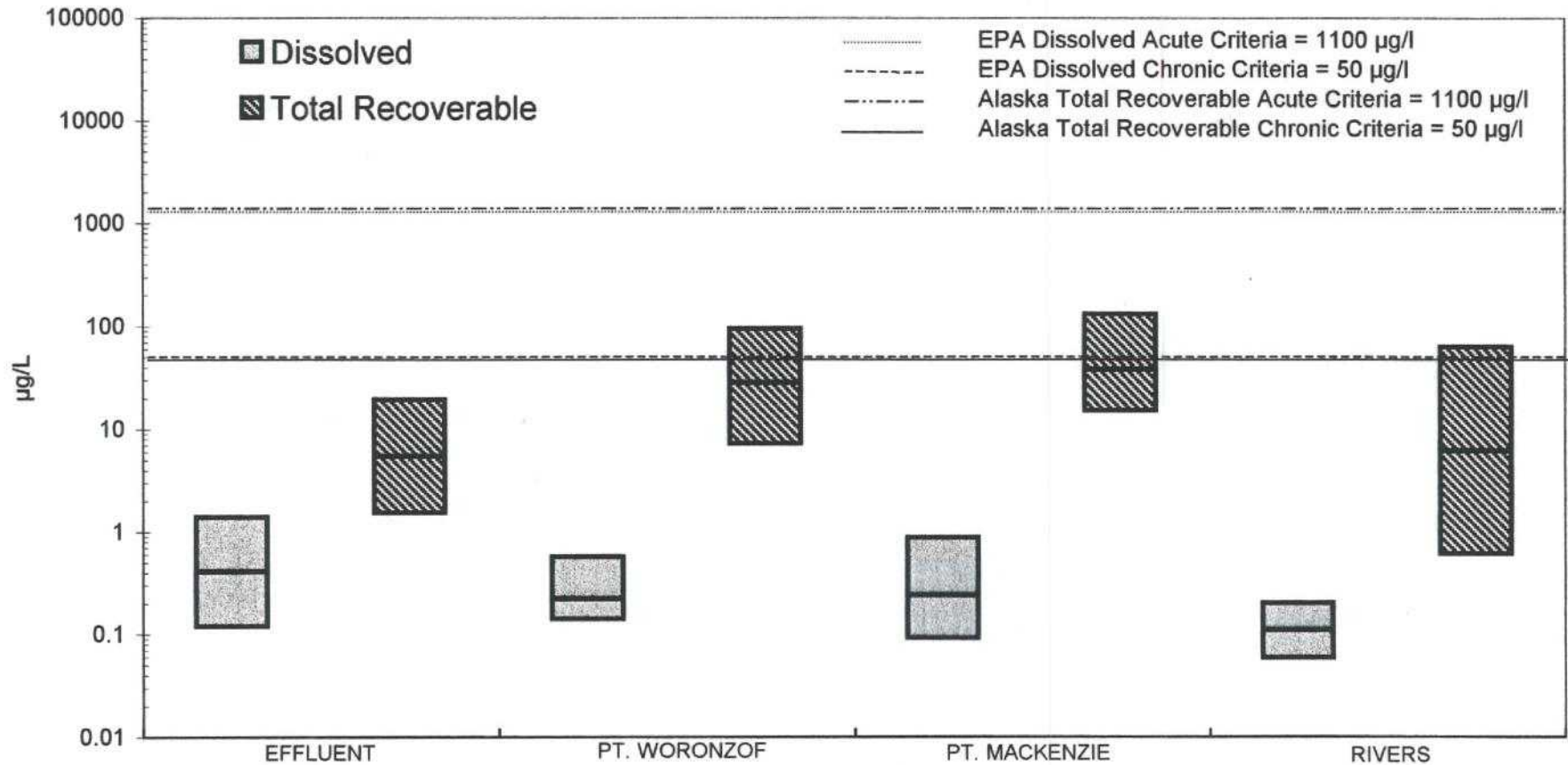
SELENIUM

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)

Figure 2-13

Concentrations of Dissolved and Total Recoverable Selenium.

SILVER

Figure 2-14

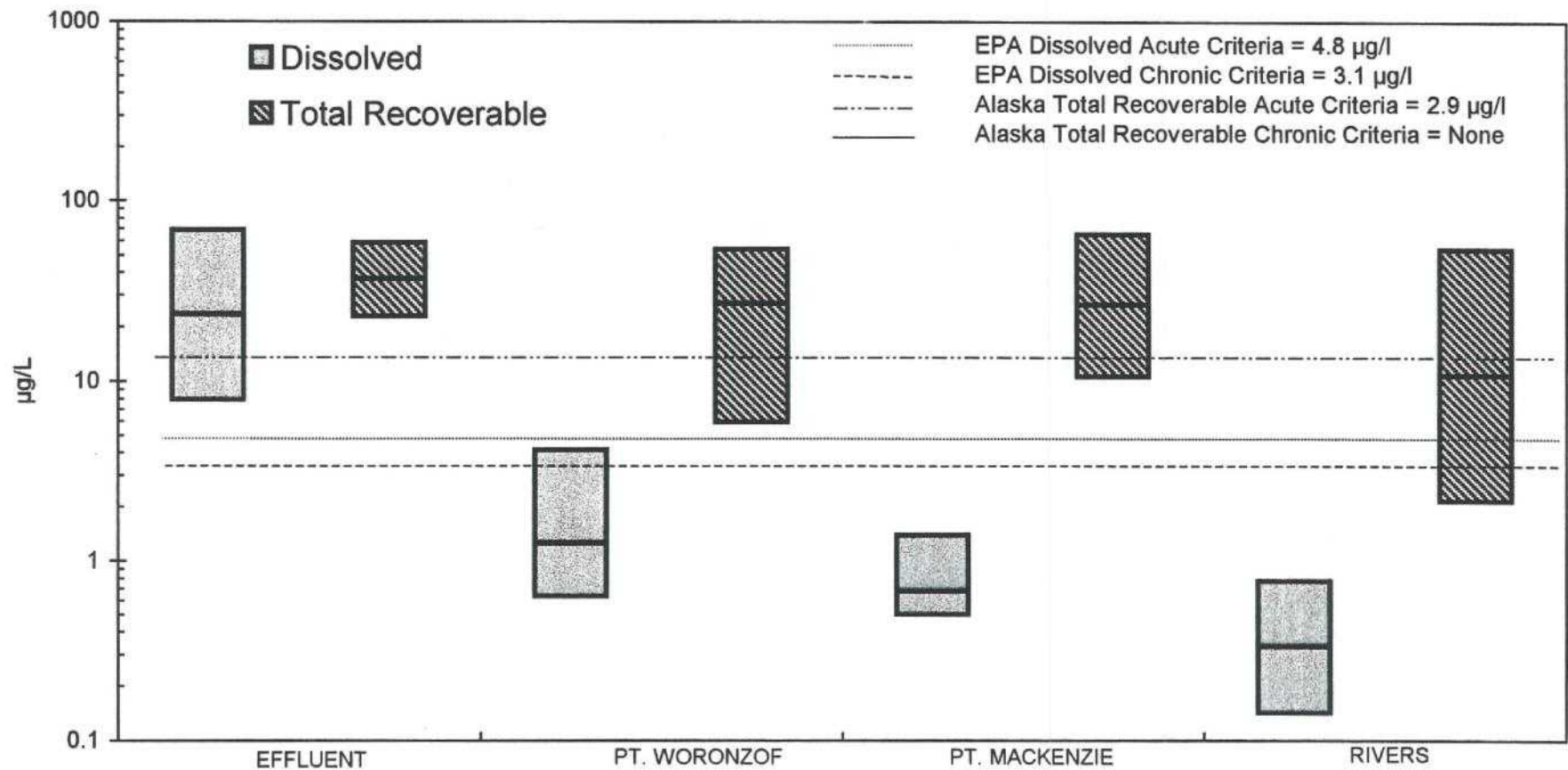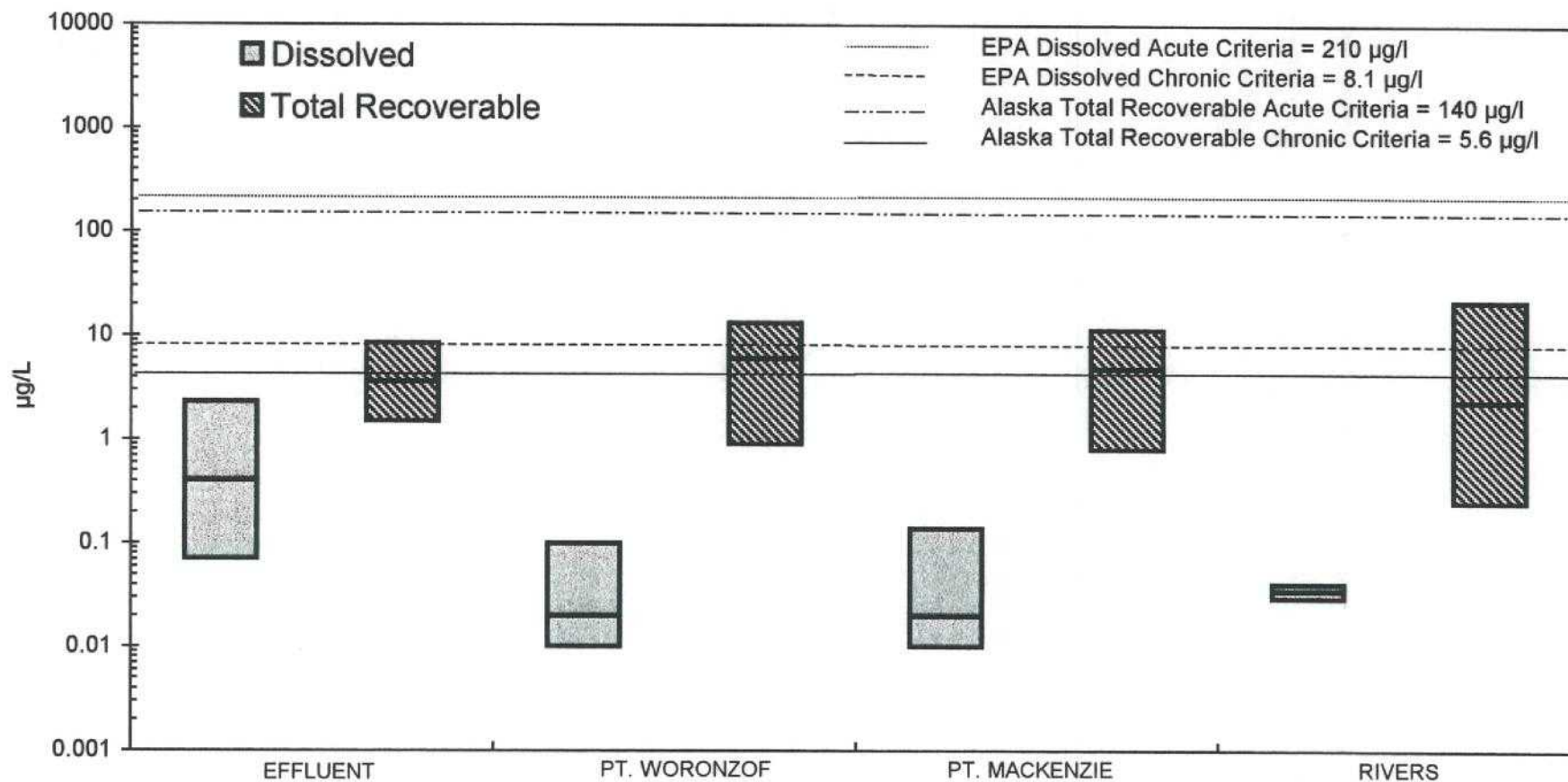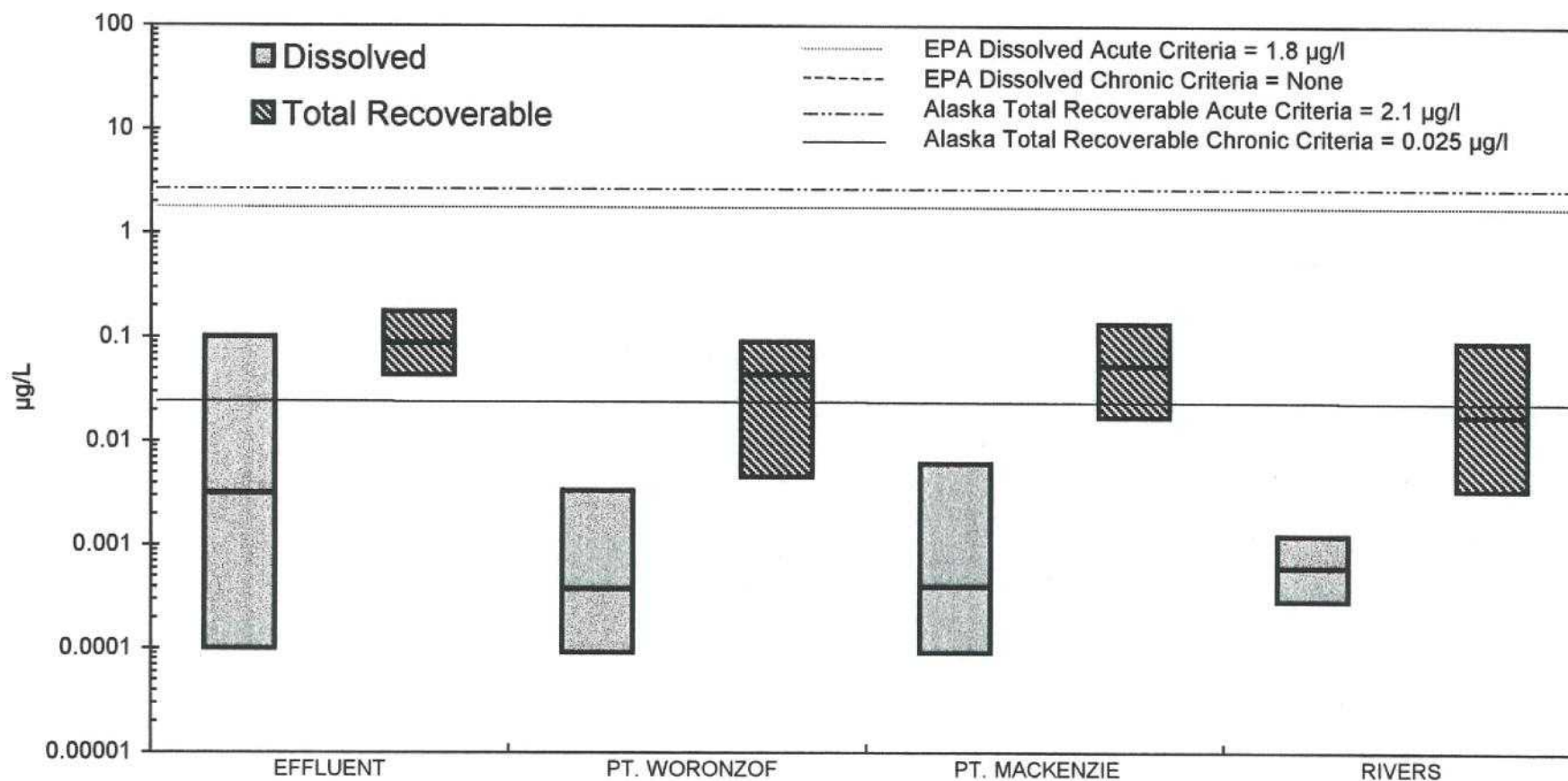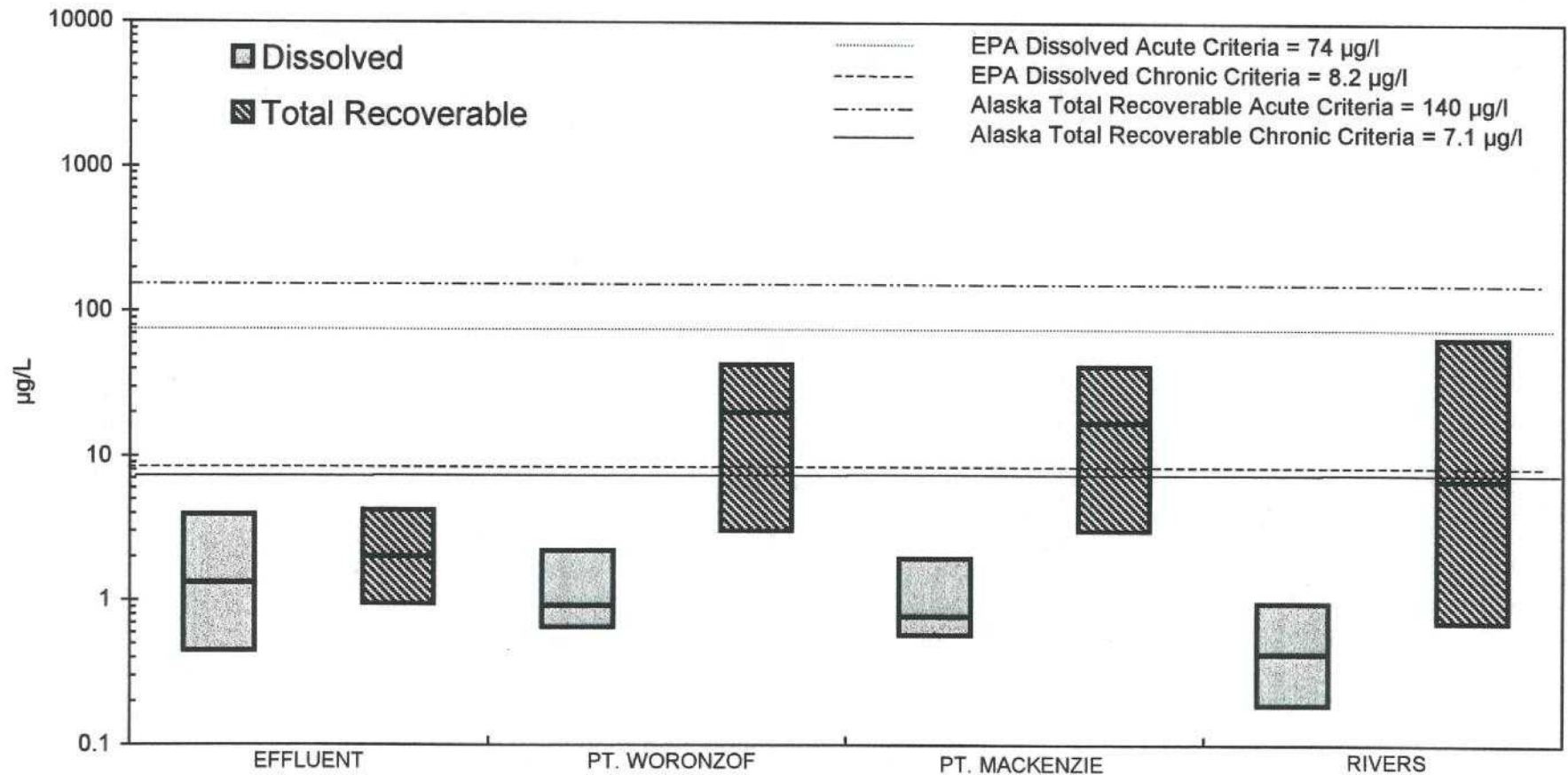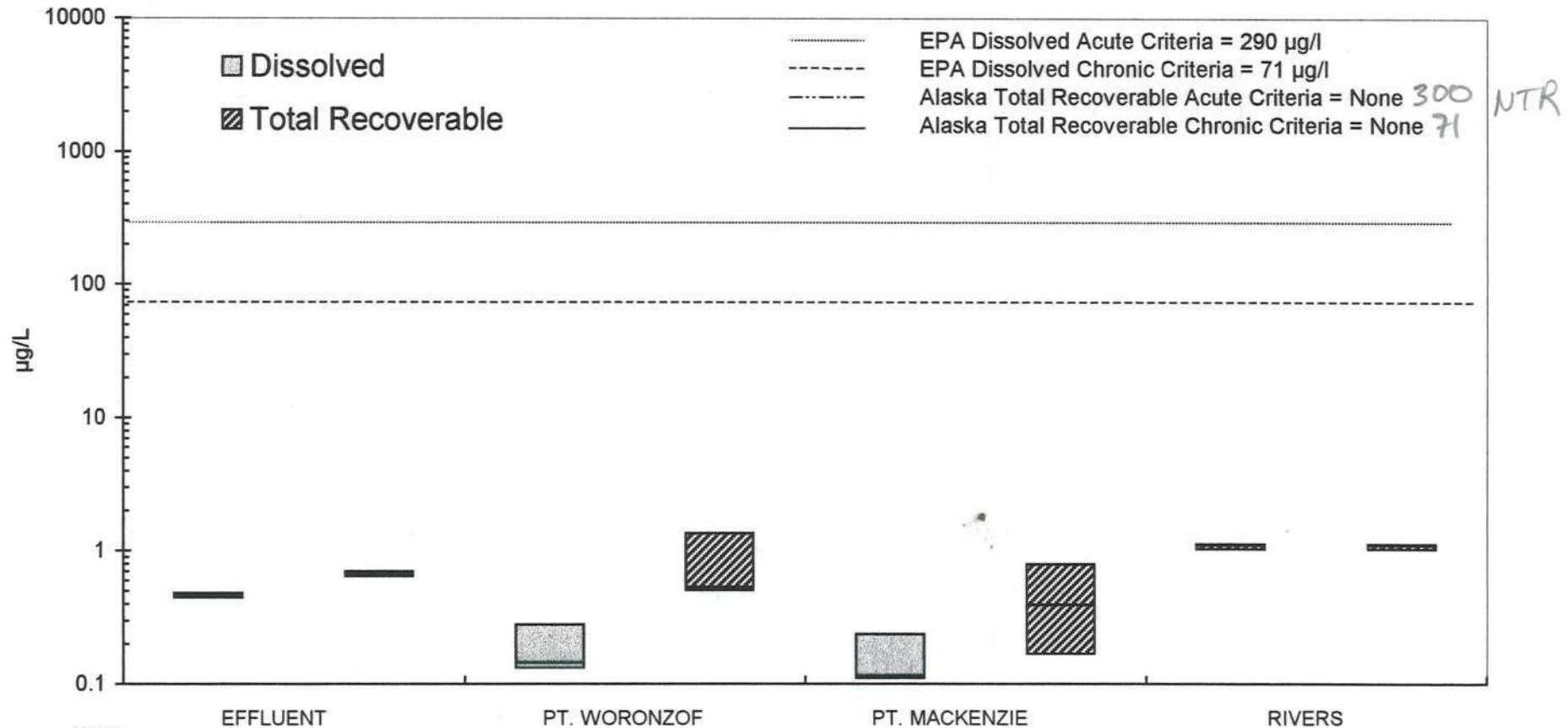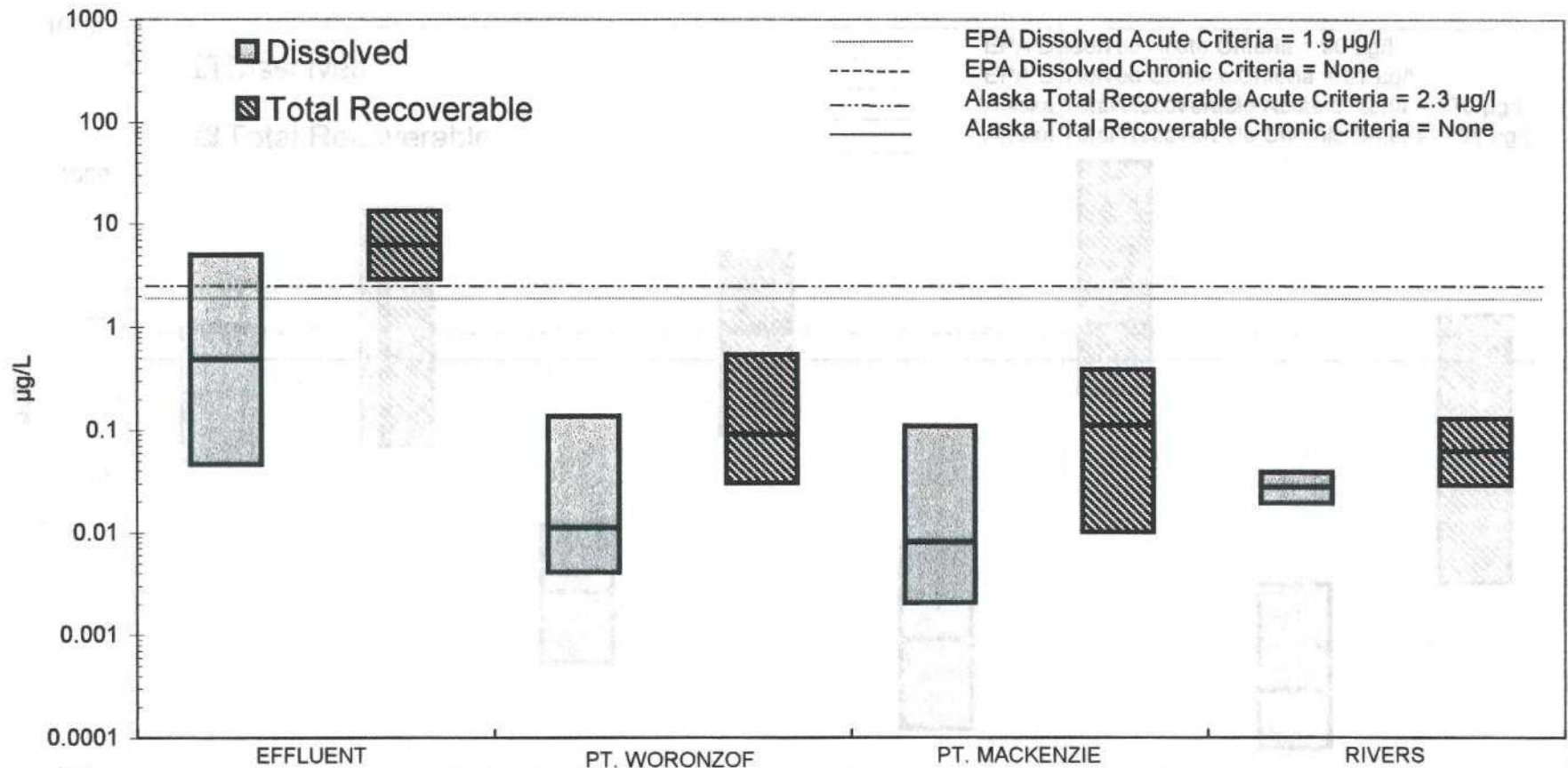**Concentrations of Dissolved and Total Recoverable Silver.**

Note:
Limits are 1st to 99th Percentile for Effluent and 5th to 95th Percentile for Pt. Woronzof, Pt. MacKenzie, and Rivers with the 50th Percentile Indicated. (Rivers and Effluent based on Log-Normal Distribution; receiving water stations based on sample population.)

3. Justification for Site Specific Criteria for Turbidity

In this section the existing water quality standard for turbidity is reviewed and compared to existing conditions. Based on the observed receiving water conditions and the expected level of human impact, proposed SSWQC are recommended for the vicinity of Point Woronzof.

3.1 Existing Conditions and Standards

The Alaska water quality standard (AWQS) for turbidity is shown below in Table 3-1. The numerical criteria for the protection of water supply (aquaculture) and recreation is 25 NTU. As described in Section 2 above, the receiving water levels of turbidity have never been observed as low as 25 NTU and are typically an order of magnitude higher (see Figure 2-2). The lowest levels observed are approximately 250 NTU at the Point Mackenzie sampling station, except for a few lower values in the surface layer (upper 1 to 2 meters). At the Point Woronzof sampling station, the lowest values observed are about 100 NTU, with a few lower values in the near surface layer.

The Point Woronzof stations are in the vicinity of a major human input, yet show lower levels of turbidity than the more distant station. This occurs because the TSS in the receiving waters, and thus the high turbidity, is a direct result of riverine input of fine sediments generated by glacial scouring of rocks in the river drainage basins. Because of the extremely high levels of suspended solids delivered by the rivers, the turbidity in the receiving waters results primarily from the suspended solids as described in Section 2. The rivers discharging into the upper portion of Knik Arm have the highest suspended solids. Therefore it is not unexpected for the Point Mackenzie samples to exhibit higher TSS, and thus higher turbidity levels than the Point Woronzof Station. This is consistent with the higher values observed further up Knik Arm, closer to the riverine inputs.

The river samples were collected upstream of most human influence, and river loads account for nearly all of the TSS observed in Knik Arm. For example, using the 1998 river and receiving water data presented in Section 2, the following approximations can be constructed:

- The average surface TSS for the Point Woronzof Stations was 220 mg/l and the average river values including the Little Susitna, was 261 mg/l. Considering that approximately 80% of the water in Knik Arm is riverine in origin (based on typical salinity values), the rivers account for about 209 mg/l, or virtually all of the TSS in the water body. The TSS load of the Little Susitna river is considerably lower than the other three rivers, but it is closer to Point Woronzof than to Point Mackenzie, and is therefore included in this calculation.

- The average TSS for the point MacKenzie Stations was 246 mg/l. The average river values including the Little Susitna was 261 mg/l, and the average excluding the Little Susitna was 340 mg/l. Using the 80 percent factor mentioned above, the rivers can be considered to account for between 209 to 272 mg/l of TSS at this station, excluding and

including the Little Susitna data, respectively. Thus, there is a strong indication that all of the TSS in the receiving water is from the riverine loadings.

The calculations presented above are rough approximations, but do illustrate that the levels of TSS, and thus turbidity, observed in the water body, can be considered mostly of natural origin, and the lowest levels observed can be considered the best prevailing natural conditions. The natural background levels of turbidity can not be expected to meet the current AWQS numerical criteria of 25 NTU.

3.2 Recommended Site Specific Criteria for Turbidity

Based on the data and discussions provided above, the following site specific criteria for turbidity, if adopted, would not result in any degradation of the water quality. It is proposed that the numerical standard be replaced with (referring to any discharge): 'May not be increased above natural levels.' The standard for the protection of marine life would remain the same as currently stated. Table 3-1 includes the proposed SSWQC and it is proposed that these criteria be applied in the area outlined in Figure 1-2.

Table 3-1 Alaska Water Quality Standards For Turbidity (Existing and Proposed)			
		Turbidity Criteria	
	(2) Marine Water Uses	Existing AWQS [a]	Proposed SSWQC [b]
(A)	Water Supply (i) aquaculture	May not exceed 25 nephelometric turbidity units (NTU).	*May not be increased above natural levels.*
(A)	Water Supply (ii) seafood processing	May not interfere with disinfection.	May not interfere with disinfection.
(A)	Water Supply (iii) industrial	May not cause detrimental effects on established levels of water supply treatment.	May not cause detrimental effects on established levels of water supply treatment.
(B)	Water Recreation (i) contact recreation	Same as (2)(A)(i).	*Same as (2)(A)(i).*
(B)	Water Recreation (ii) secondary recreation	Same as (2)(A)(i).	*Same as (2)(A)(i).*
(C)	Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	May not reduce the depth of the compensation point for photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.	May not reduce the depth of the compensation point for photosynthetic activity by more than 10%. May not reduce the maximum secchi disk depth by more than 10%.
(D)	Harvesting for Consumption of Raw Mollusks or other Raw Aquatic Life	Same as (2)(C).	Same as (2)(C).
[a] Taken from Alaska Water Quality Standards, 18 AAC 70, Alaska Department of Environmental Conservation, November 1, 1997. [b] Entries in ***bold italic*** are proposed changes			

in the water than does total recoverable metal...EPA recommends that State water quality standards be based on dissolved metal."

<table>
<tr><td colspan="2" align="center">Table 4-1
Existing Alaska Water Quality Standards For
Toxics And Other Deleterious Organic And Inorganic Substances</td></tr>
<tr><td>(2) Marine Water Uses</td><td align="center">Existing AWQS [a]</td></tr>
<tr><td>(A)   Water Supply
     (i) aquaculture</td><td>Same as (2)(C).</td></tr>
<tr><td>(A)   Water Supply
     (ii) seafood processing</td><td>Individual substances may not exceed criteria in EPA, <i>Quality Criteria for Water</i> (See Note 5) as applicable to the substance.</td></tr>
<tr><td>(A)   Water Supply
     (iii) industrial</td><td>Substances that pose hazards to worker contact may not be present.</td></tr>
<tr><td>(B)   Water Recreation
     (i) contact recreation</td><td>Same as (2)(A)(ii).</td></tr>
<tr><td>(B)   Water Recreation
     (ii) secondary recreation</td><td>Substances that pose hazards to incidental human contact may not be present.</td></tr>
<tr><td>(C)   Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife</td><td>Individual substances may not exceed criteria in EPA, <i>Quality Criteria For Water</i> (See note 5) or, if those criteria do not exist, may not exceed the Primary Maximum Contaminant Levels of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by EPA or alternate methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests (See note 5)</td></tr>
<tr><td>(D)   Harvesting for Consumption of Raw Mollusks or other Raw Aquatic Life</td><td>Same as (2)(C).</td></tr>
<tr><td colspan="2">Note 5: The term "EPA Quality Criteria for Water" includes Quality Criteria for Water, July 1976, United States Environmental Protection Agency, Washington D.C. 20460, United States Government Printing Office: 1977 0-222-904, the Ambient Water Quality Criteria for the 64 toxic pollutants listed in the Federal Register, Vol. 45, No. 231, pg. 79318, November 1980, the Ambient Water Quality Criteria Document for 2, 3, 7, 8-tetrachlorodibenzopdioxin (TCDD) listed in the Federal Register, Vol. 49, No. 32, pg. 5831, February 1984, and the final ambient water quality criteria documents listed in the Federal Register, Vol. 50, No. 145, pg. 30784, July 1985. These documents may be seen at the department's Juneau office or may be purchased through the National Technical Information Service, United States Department of Commerce, Springfield, Virginia 22161.</td></tr>
<tr><td colspan="2">[a] Taken from Alaska Water Quality Standards, 18 AAC 70, Alaska Department of Environmental Conservation, November 1, 1997.</td></tr>
</table>

Table 4-2
Measured Background Concentrations, Existing AWQS, and EPA Interim Final Rule Dissolved Criteria for Metals

Metal		Total Recoverable 95th percentile		Dissolved 95th percentile		AWQS		EPA Dissolved Criteria	
		Point MacKenzie	Point Woronzof	Point MacKenzie	Point Woronzof	CCC (acute)	CMC (chronic)	CCC (acute)	CMC (chronic)
Arsenic	µg/l	32.4	17.35	1.875	2.37	69	36	69	36
Cadmium	µg/l	0.435	0.810	0.056	0.070	43	9.3	42	9.3
Chromium	µg/l	117.0	88.0	0.790	0.433	1100	50	1100	50
Copper	µg/l	54.7	48.2	0.89	3.52	2.9	none	4.8	3.1
Lead	µg/l	10.7	12.6	0.13	0.089	140	5.6	210	8.1
Mercury[1]	µg/l	0.119	0.0864	0.00605	0.00329	2.1	0.025	1.8	none[1,2]
Nickel	µg/l	38.5	40.1	1.37	1.57	140 (75)[3]	7.1 (8.3)[3]	74	8.2
Selenium	µg/l	0.623	0.830	0.122	0.149	none (300)[3]	none (71)[3]	290	71
Silver	µg/l	0.38	0.510	0.107	0.132	2.3	none	1.9	none
Zinc	µg/l	1240	302.0	2.35	3.11	170 (95)[3]	58 (86)[3]	90	81

[1] Mercury criteria should be based on protection of human health described in Section 5 of this document, for reference EPA's California toxic rule levels for chronic exposure for aquatic life is 0.94 µg/l and human health criterion is 0.51 as total recoverable.
[2] The EPA chronic citerion for Mercury is 0.025 µg/l based on the total recoverable fraction.
[3] Criteria in parentheses are ADEC proposed revisions to the existing total recoverable criteria.

Subsequent to the promulgation of the Metals Policy, EPA (1997) has issued a toxics rule for California based on the dissolved criteria. An exception in the California Toxics Rule to the dissolved fraction approach promulgated in 1995 were criterion continuous concentrations (chronic exposure for aquatic life) for mercury. In the California toxics rule a chronic criterion for dissolved mercury was listed (0.94 µg/l). However, the human health criterion listed in this rule were not based on dissolved mercury. The criterion listed were 0.050 and 0.051 µg/l for consumption of water and organisms, and consumption of organisms only, respectively. Because mercury bioaccumulates, a scientifically defensible criterion should be based on assessment human health risk including considerations of exposure pathways and exposure levels. This is discussed in Section 5 below, which supports the proposed SSWQC.

In revising the metals criteria, EPA (1995) held that the criteria based on dissolved metals are protective of aquatic life and better approximate the biologically available fraction of water borne metals compared to previous criteria based on total recoverable metals concentrations. EPA considers the use of total recoverable fraction to be more stringent than necessary to protect designated uses for aquatic life. It is the aim of both the Clean Water Act EPA policy that the States incorporate new science into the water quality program by promulgating their own standards and implementation policies.

4.3 Recommended Site Specific Criteria for Metals (except Mercury)

Based on the data and discussions provided above, the following site specific criteria for metals would protect marine life to the same degree as the current criteria. It is proposed that the numerical criteria for all metals (except mercury) be based on dissolved fraction following the EPA Metals Policy and Final Interim Rule (EPA, 1995; 1997). The proposed numerical criteria (except for mercury) are those promulgated by EPA and listed in the right hand column of Table 4-2 above.

It is recommended that this SSWQC be applied to all metals (except mercury) for consistency since the use of the dissolved fraction has been determined to be the appropriate, scientifically defensible, approach. Table 4-3 presents the proposed SSWQC, in the context of the existing AWQS from Table 4-1, and the proposed area for application of the SSWQC is that shown in Figure 1-2. Justification for the mercury criteria is discussed in more detail in Section 5 below.

Table 4-3
Proposed Site Specific Water Quality Standards For
Toxics And Other Deleterious Organic And Inorganic Substances

(2) Marine Water Uses		Proposed SSWQS
(A)	Water Supply (i) aquaculture	*Same as (2)(C).*
(A)	Water Supply (ii) seafood processing	Individual substances may not exceed criteria in EPA, *Quality Criteria for Water* (See Note 5) as applicable to the substance. *With the exceptions noted in 2C.*
(A)	Water Supply (iii) industrial	Substances that pose hazards to worker contact may not be present.
(B)	Water Recreation (i) contact recreation	*Same as (2)(A)(ii).*
(B)	Water Recreation (ii) secondary recreation	Substances that pose hazards to incidental human contact may not be present.
(C)	Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Individual substances, *with the exception of the specific metals listed below*, may not exceed criteria in EPA, *Quality Criteria For Water* (See note 5) or, if those criteria do not exist, may not exceed the Primary Maximum Contaminant Levels of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by EPA or alternate methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests (See note 5).
		The numerical criteria for the specific metals listed below will be, based on the dissolved fraction of those metals, as follows (µg/l):

(metals table)

	CCC	*CMC*
Arsenic	*69*	*36*
Cadmium	*42*	*9.3*
Chromium (VI)	*1100*	*50*
Copper	*4.8*	*3.1*
Lead	*210*	*8.1*
Mercury	*1.8*	*0.025*
Nickel	*74*	*8.2*
Selenium	*290*	*71*
Silver	*1.9*	
Zinc	*90*	*81*

| (D) | Harvesting for Consumption of Raw Mollusks or other Raw Aquatic Life | *Same as (2)(C).* |

Note 5: The term "EPA Quality Criteria for Water" includes Quality Criteria for Water, July 1976, United States Environmental Protection Agency, Washington D.C. 20460, United States Government Printing Office: 1977 0-222-904, the Ambient Water Quality Criteria for the 64 toxic pollutants listed in the Federal Register, Vol. 45, No. 231, pg. 79318, November 1980, the Ambient Water Quality Criteria Document for 2, 3, 7, 8-tetrachlorodibenzopdioxin (TCDD) listed in the Federal Register, Vol. 49, No. 32, pg. 5831, February 1984, and the final ambient water quality criteria documents listed in the Federal Register, Vol. 50, No. 145, pg. 30784, July 1985. These documents may be seen at the department's Juneau office or may be purchased through the National Technical Information Service, United States Department of Commerce, Springfield, Virginia 22161.

[b] Entries in *bold italic* are proposed changes to AWQS

5. Justification for Site Specific Criteria for Mercury

This section addresses the nature of mercury in the environment in terms of the biogeochemistry of mercury in the Knik Arm of Cook Inlet. The mercury cycle is described as well as the natural and anthropogenic sources of mercury to upper Cook Inlet. The FDA action level for mercury is described in terms of the meaning of the action level and a comparison to measured fish tissue levels from upper Cook Inlet. The sources of mercury bioconcentration in fish are described along with a discussion of the measured fish-tissue and receiving water concentrations. Consideration is given to use of dissolved Hg for a site-specific criteria based on the bioconcentration observed. The human health risk of ingestion of mercury contaminated fish from upper Cook Inlet is assessed based on reasonable maximum exposure and typical exposure assumptions. A recommendation for a site-specific criteria for mercury is made based on fish tissue levels and the above described discussions.

5.1 Biogeochemistry of Mercury

To understand the problems posed by mercury in the aquatic environment one must have a general knowledge of the biogeochemistry of mercury. The biogeochemistry of a substance includes its chemical and geological characteristics as well as the biological transformations the substance undergoes in the natural environment. Mercury is a heavy metal that enters aquatic systems from anthropogenic and natural sources and can exist in aquatic systems in inorganic and organic forms. However, the organic form of mercury, methylmercury, is primarily responsible for any potential risks to the beneficial uses of aquatic systems. This section describes the mercury cycle and the anthropogenic and natural sources of mercury to Cook Inlet.

Elemental mercury (Hg) is a silver-white volatile metal that is liquid at room temperature. Inorganic mercury compounds include Hg, mercurous (Hg_2^{2+}), and the mercuric (Hg^{2+}) ion states (Eisler, 1987) and all three forms can be incorporated into inorganic and organic compounds (EPA, 1980; Clarkson et al., 1984). Organic mercury compounds are covalently bound to carbon, such as methylmercury ($HgCH_3$), and phenylmercury (HgC_6H_5). The organic mercury compounds are considered biologically significant (Hrudey, et.al, 1996). Figure 5-1 shows the mercury cycle and the transport and transformation processes, labeled as numbered pathways for discussion purposes, numbered from one to eight. Pathway one (1) is atmospheric deposition, two (2) is watershed input, three (3) is sedimentary deposition and resuspension, four (4) and five (5) are sedimentary dissolution, six (6) is bacterial methylation in sediments and from the sediments to the water column, seven (7) is evaporation to the atmosphere, and eight (8) is bioconcentration. Each of pathways is described briefly below with more in depth discussion reserved for pathways of greater importance in upper Cook Inlet. A mercury budget for upper Cook Inlet is well beyond the scope of this study.

Atmospheric Inputs
Figure 5-1, pathway (1), denotes the atmosphere, which is one source of mercury to aquatic systems. The atmosphere plays a major role in the global dispersal of mercury. Mercury vapor, accounting for 60 percent of atmospheric Hg, can be from natural (mercuric deposits, volcanic action, and natural degassing) or anthropogenic (fossil fuel combustion, mercury mining, and manufacturing) sources. The mercury in the atmosphere consists primarily of the mercuric ion (Hg^{+2}), elemental mercury

Sedimentary Deposition, Resuspension, and Dissolution

Figure 5-1, pathway (3), represents the phenomena of deposition and resuspension. Whether the particulate mercury compounds originate in the atmosphere or the watershed, upon entering a water body they will either be deposited or remain in suspension. In addition, previously deposited particulate mercury can be resuspended. Offshore of Anchorage the Cook Inlet bottom is made up of coarse gravel and cobble, and there is little fine grained sediment accumulation in the offshore locations. All of upper Cook Inlet is fringed with mud flats and Knik Arm has extensive mud flats. In the mud flat areas there is accumulation of fine grained sediment.

Figure 5-1, pathway (4), represents the dissolution of particulate mercury to the mercuric ion and the precipitation of particulate mercury from the mercuric ion in the sediment.

Water Column Dissolution

Figure 5-1, pathway (5), represents the dissolution of particulate mercury to the mercuric ion and the precipitation of particulate mercury from the mercuric ion in the water column. The rate of dissolution of particulate mercury increases with decreasing pH. The conditions in Cook Inlet controlling dissolution are described below.

Dissolution and Bacterial Methylation

Figure 5-1, pathway (6), represents mercury bacterial methylation in both the sediment and the water column. Sediment as well as decomposing fish contain microorganisms that form methylmercury and di-methylmercury from inorganic mercury under aerobic and anaerobic conditions (Tollefson, 1989). Mercury in the mercuric (Hg^{+2}) form must be available in order for methylation of any type to take place (Beijer and Jernelov, 1979). When the mercuric ion is methylated, methylmercury is the result. Methylmercury (CH_3Hg^+) is by far the most bioavailable form of mercury and therefore the primary mercury species of concern in the aquatic environment. The hazards of methylmercury are due to its high stability, lipid solubility, and ionic properties that lead to a high ability to penetrate membranes in living organisms (Beijer and Jernelov, 1979).

In aquatic systems, mercury may be methylated both chemically and biologically or through a mixed process (Beijer and Jernelov, 1979). Methylmercury is formed primarily in sediments where sulfate bacteria are present (Baldi et al., 1995) but can also be formed by bacteria in water bodies with high concentrations of particulates and organic matter. Olson and Cooper (1972) found greater net methylation rates in anaerobic marine sediment than in aerobic sediment and the highest rates of methylation in sediments with high organic content. Methylation can also occur abiotically, however the net effect of abiotic methylation on the amount of methylmercury present in the system is small (Miskimmin et al., 1992). The efficiency of biological methylation is dependent on the metabolic activity of the methylating organisms, which in turn depends on the availability of organic substrate and the temperature. Efficiency also depends on the total concentration of inorganic mercury and the biochemical availability of inorganic mercury, which in turn depends on the redox potential, pH, and the presence of sulfides and other organic and inorganic complexing agents (Beijer and Jernelov, 1979). Once methylmercury is formed in the sediments or suspended sediments it is rapidly and effectively taken up by aquatic organisms.

The hydrographic conditions in upper Cook Inlet of importance in the consideration of mercury methylation include dissolved oxygen, pH, and dissolved organic carbon. Dissolved oxygen data indicate that the Knik Arm waters of upper Cook Inlet are near saturation and have little vertical stratification. DO concentrations ranged from 7.5 mg/L to 11.0 mg/l, depending on the temperature (CH2M HILL, 1998). The pH data for Cook Inlet indicates mildly basic conditions with pH readings ranging from 7.7 to 8.2 (CH2M HILL, 1998). Dissolved organic carbon is assumed to be low judging by the low primary productivity in the Knik Arm of Cook Inlet (CH2M HILL, 1998).

The sediment conditions in the Knik Arm of Cook Inlet are also important in the consideration of mercury methylation. Sediment samples taken offshore of Anchorage show low levels of BOD (0.3 to 0.7 mg/L). The combination of low BOD, aerobic conditions, and limited sediment deposition in the offshore portions of upper Cook Inlet suggest that the formation of methylmercury will be limited in these areas. In addition, the combination of slightly elevated pH, low organic content, and high dissolved oxygen in the water column suggests that there will be limited methylmercury formation in the water column as well. Another consideration for weighing the contribution to the water column from mercury methylation is that the non-dissolved fraction of mercury in the sediments, derived from terrigenous runoff, is tightly bound to mineral particles and thus largely unavailable for conversion.

In mudflat areas of Knik Arm and upper Cook Inlet, there is a higher potential for contribution of methylmercury from bacterial methylation because of the higher organic content of sediments and higher levels of anaerobic bacteria. In contrast to these biological processes, the frequent, large, and rapid tidal exchanges in Knik Arm make the residence time of watershed runoff carrying suspended sediments laden with inorganic dissolution resistant HgS very short. Suspended sediments in upper Cook Inlet have been shown to contain total rather than dissolved mercury that is flushed from the system rapidly, not allowing sufficient time for methylation or dissolution. It is known that sediments containing mercury bound to inorganic minerals is largely unavailable for methylation and also unavailable to deposit feeding marine macroinvertebrates (Windom and Kendall, 1979). Suspended sediments containing mercury bound to organic matter in upper Cook Inlet and Knik Arm mudflats have a greater chance of supplying methylmercury to the mudflat if deposited in regular and sufficient quantities in undisturbed small pockets within the estuary, such as in pool areas within salt marshes. These small areas are not considered sufficient to supply a measurable amounts of MeHg to the system. The background concentrations of MeHg in upper Cook Inlet water column show non-detectable levels at 0.0000320 µg/L for both total and dissolved MeHg (Table 5-1)

Table 5-1 Total and Dissolved Methylmercury at Point MacKenzie Receiving Water Station			
Sample Location	Sample ID	Total MeHg (µg/L)	Dissolved MeHg (µg/L)
2C1-1SR	MSR98MHG0007	0.0000320 U	0.0000320 U
2C1-2SR	MSR98MHG0008	0.0000320 U	0.0000320 U
2C1-3SR	MSR98MHG0009	0.0000320 U	0.0000320 U
Blank			0.0000320 U

Bioconcentration

Figure 5-1, pathway (8), represents the bioconcentration of mercury in aquatic organisms. The overriding concern regarding mercury in the environment is its tendency to accumulate in fish and other organisms that are consumed by humans (Huckabee et al., 1979). This bioaccumulation occurs as organisms contaminated with mercury are consumed by other organisms higher on the food chain. Accumulation in bottom fauna is followed by accumulation in fish species. As the trophic level of the fish increases the intake of high protein food becomes more important. Large carnivorous fish at the top of the aquatic food chain are found to accumulate the largest amounts of methylmercury (Tollefson, 1989).

Mercury available to fish can come from the water column and the intake of food (Phillips and Buhler, 1978). In either case the entry into a fish's body are by way of the gills and digestive tract (Huckabee et al., 1978; Rudd et al., 1980). Inorganic mercury is not easily absorbed by fish and is more readily purged from the body compared to methylmercury. It has been reported that 90 to 99% of mercury detected in fish tissue is methylmercury (Huckabee et al., 1978;Grieb et al., 1990; Bloom, 1992). It has also been observed that methylation of inorganic mercury does not occur within fish tissue but rather it can be absorbed into the body via the gills and gut (Pennacchioni et al., 1976; Phillips and Buhler, 1978). Methylation of mercury by microorganisms (bacteria) can occur in the sediments and water column as described in pathway six above, as well in the slime layer coating on the exterior of fish and the gut fauna in the interior of the fish (Rudd et al., 1980). Phillips and Buhler (1978) reported assimilation of 10% of available water column methylmercury and 70% of available ingested methylmercury by rainbow trout (*Oncorhynchus mykiss*). The assimilation efficiency of methylmercury in the diet of fish has been proposed at 65 to 80 % or greater (Phillips and Buhler, 1978; Rodgers, 1994)

Once methylmercury is assimilated (via digestive tract or gills) it binds to red blood cells and is transported to the organs of the body (Giblin and Massaro, 1973; Olsen et al.,1978; Harrison et al., 1990). From the organs, methylmercury is distributed to the tissues and muscles of the body (Harrison et al., 1990). The end result is the accumulation of methylmercury in the muscles bound to sulfhydryl groups in protein (Giblin and Massaro 1973, Olsen et al. 1978, Harrison et al. 1990).

In mammals, when methylmercury is expelled from the body into the digestive tract, it can be reabsorbed, demethylated into inorganic mercury by microbial demethylation in the gut, and to a limited extent passed out with the feces. Due to the efficiency of methylmercury assimilation, most of the methylmercury is reabsorbed and only inorganic mercury is passed out of the body with the feces. In fish, there is currently no evidence of microbial demethylation in the gut (Beyer et al., 1996). Huckabee et al. (1975) reported a half-retention time of methylmercury in mosquito fish (*Gambusia affinis*) of over a year and Lockhart et al. (1972) reported almost two years for northern pike (*Esox lucius*). Rainbow trout have been reported with a half-retention time for methylmercury from seven months to almost a year and a half (Giblin and Massaro,1973; Rouhtula and Miettinen, 1975). In areas where methylmercury intake, even at very low levels, exceeds methylmercury excretion, bioaccumulation in the fish occurs.

Even at a modest estimate, well over half the methylmercury assimilated by fish comes from diet (Phillips and Buhler, 1978; Huckabee et al.,1978; Rudd et al., 1980). Studies have shown that

methylmercury biomagnifies in aquatic food chains (Wren et al., 1983; Francesconi and Lenanton, 1992; Watras and Bloom, 1992). Food chain structure and feeding habits influence the amount of methylmercury available for assimilation (Beyer, 1996). Fish readily assimilate methylmercury contained within the food they eat so it is not surprising that piscivorous fishes usually contain higher concentrations of methylmercury than coexisting fish of lower trophic levels (Phillips et al., 1980; Wren et al., 1983; Francesconi and Lenanton. 1992). Since the majority of fish species consumed by humans are piscivorous varieties, and since the muscles of the fish are generally the portions of the fish consumed, bioaccumulation of methylmercury within fish muscle tissue remains a prominent issue.

Large carnivorous fish at the end of the food chain are found to accumulate the largest amounts of methylmercury (Tollefson, 1989). The longer-lived, predatory organisms can eventually develop significantly elevated mercury concentrations in their tissue. Even though there is little documented evidence of mercury toxicity to fish in natural waters (Armstrong, 1979), there is a risk to human health from consumption of fish that have accumulated mercury in their tissues. Monitoring data shows that the discharge of mercury to the aquatic environment has primarily been made up of elemental mercury (Hg^0) and divalent inorganic mercury (Hg^{+2}), yet the analysis of fish tissue has shown that the accumulated mercury is almost exclusively methylmercury (Bisogni, 1979). Regulatory criteria is aimed at protecting the beneficial use of aquatic systems from mercury and focuses on the pathways to methylmercury formation and documented levels of methylmercury found in organisms in a particular environment.

5.2 Fish Tissue Analysis for Mercury

In addition to the sampling for metals in the receiving water and rivers, samples to determine the fish tissue levels of mercury in upper Cook Inlet were collected. Samples of migratory fish (Coho salmon) and indigenous fish (Saffron cod) were obtained by Kinnetic Laboratories and analyzed by Battelle Marine Science Laboratories. The Coho salmon used for the tissue analysis are commonly available during their migration to rivers draining into upper Cook Inlet. The salmon are an important commercial species and widely used in the local and exported food supply. The salmon used for analysis were caught commercially at Fire Island in upper Cook Inlet near the mouth of Knik Arm, on 17 August 1998 and received by the laboratory on August 19th. Five samples, plus one replicate, from individual female Coho salmon, weighing 8 to 10 pounds, were tested. The tissue analysis results for the salmon are presented in Table 5-2. The results indicate an average muscle tissue methylmercury burden in the Coho salmon samples of 0.045 µg/g on a wet weight basis.

As a comparison to the migratory salmon a resident fish, Saffron cod *(Eleginus gracilis)*, was also chosen for tissue analysis. Saffron cod are common in Cook Inlet and their range includes the nearshore coastal waters of the eastern Pacific from Sitka, Alaska through the Bering, Chukchi, and Beaufort seas. Saffron cod have a short onshore and offshore migration moving inshore (0 - 25 meters) to spawn in the winter and moving offshore (30 - 60 meters) during the spring and summer to feed. Saffron cod adults are semidemersal and feed on benthic, epibenthic, and pelagic invertebrates. The Alaska Department of Fish and Game (1986) indicate that Saffron cod are important in the diets of seals and Beluga whales but not a fish commonly used by humans. The samples of Saffron cod were collected on October 9, 1998, using beach seines from one location in upper Cook Inlet. The

beach seine station was located immediately south of the boat launch in Anchorage, about 250 meters south of Ship Creek. Five samples were collected with three fish per composite. Samples were received by the laboratory on 10/13/98 and analyzed for total and mercury and methylmercury, as with the salmon samples. The results for the Saffron cod are presented in Tables 5-3. The results indicate an average muscle tissue methylmercury burden in Saffron cod of 0.052 μg/g on a wet weight basis.

Table 5-2
Fish Tissue Sample Results - Coho Salmon from Upper Cook Inlet

Sample ID	Percent Moisture	Total Mercury		Methylmercury	
		(μg/g dry wt.)	(μg/g wet wt.)	(μg/g dry wt.)	(μg/g wet wt.)
MSR98MHG0001	72.2	0.210	0.0584	0.175	0.0487
MSR98MHG0002 (r1)	73.6	0.197	0.0520	0.165	0.0436
MSR98MHG0002 (r2)	73.6	0.209	0.0552	0.169	0.0446
MSR98MHG0003	71.0	0.197	0.0571	0.160	0.0464
MSR98MHG0004	72.3	0.173	0.0479	0.140	0.0388
MSR98MHG0005	73.3	0.202	0.0539	0.172	0.0459
Average			0.0541		0.0447
Method Blank		0.0731		0.00659	
Detection Limit		0.0006		0.00353	

Note: Data Not Blank Corrected

Table 5-3
Fish Tissue Sample Results - Saffron Cod from Upper Cook Inlet

Sample ID	Percent Moisture	Total Mercury		Methylmercury	
		(μg/g dry wt.)	(μg/g wet wt.)	(μg/g dry wt.)	(μg/g wet wt.)
MSR98MHG0010	80.8	0.206	0.0396	0.186	0.0357
MSR98MHG0011 (r1)	81.1	0.198	0.0374	0.193	0.0365
MSR98MHG0011 (r2)	81.1	0.199	0.0376	NA	NA
MSR98MHG0012	80.8	0.277	0.0532	0.230	0.0442
MSR98MHG0013 (r1)	81.5	0.333	0.0616	0.334	0.0618
MSR98MHG0013 (r2)	81.5	NA	NA	0.311	0.0575
MSR98MHG0014	81.0	0.396	0.0752	0.398	0.0756
Average			0.0508		0.0519
Method Blank		0.0037		0.00559	
Detection Limit		0.0006		0.00559	

Note: Data Not Blank Corrected
NA = Not Available

In these samples the MeHg tissue levels for the migratory salmon and the resident Saffron cod, show a slight difference in averages of 0.007 μg/g. The migratory salmon samples had a smaller range between the smallest and largest MeHg concentration (with a 0.0099 μg/g difference) than that of the resident Saffron cod (with a 0.0399 μg/g difference). This suggests a potentially higher MeHg variability in the resident species than in the migratory species.

The results are consistent with other available data for fish tissue in Cook Inlet recently collected during the Cook Inlet Contaminant Study conducted by EPA and presented in the Preliminary Findings (EPA, 1998). The EPA sampling was done near the mouth of the Cook Inlet (Seldovia, Port Graham, and Nanwalek) and at one station in upper Cook Inlet (Tyonek). Only Salmon (Chinook and Sockeye) were sampled at the Tyonek location and the results (preliminary findings) indicate methylmercury burdens are below the level of concern. Levels of concern for the EPA study were based on consumption limits greater than 12 (8-ounce) meals per month. Potential levels of concern were exceeded only for Sea Bass taken in the Port Graham sampling area. Table 5-4 summarizes the preliminary findings for salmonid species collected in the EPA study.

Table 5-4
Preliminary Results for MeHg in Salmon
EPA Cook Inlet Contaminant Study

Species	Number of Samples (Number of Detects)	Collection Area (number of samples analyzed/ number of individuals)	Methylmercury (µg/g) Wet Weight
Chinook Salmon	6 (6)	Seldovia (2/5) Port Graham (1/5) Tyonek (2/4 and 5) Tyonek (1/1)	0.0373
Chum Salmon	2 (2)	Port Graham (2/2 to 6)	0.0198
Sockeye Salmon	9 (9)	Seldovia (3/5) Nanwalek(3/5) Tyonek (3/5)	0.0148
Note: ½ the detection limit used as concentration where no contaminant was detected for species with at least one detected concentration			

Consistent with the fish tissue levels described above, studies conducted on beluga whales in Cook Inlet have shown that the mercury concentrations in the livers are essentially the same as found in the same species in open ocean waters. A study conducted by Becker (1995) measured MeHg content of the liver of six beluga whales (*Delphinapterus leucas*) collected from Cook Inlet. The study included liver tissue samples from 3 adult males, 2 adult females, and 1 female fetus. The results indicated the adult beluga liver MeHg ranged from 0.34 to 2.11 µg/g wet weight, and the fetus had a liver concentration of 0.09 µg/g wet weight. Becker (1995) indicated that the Cook Inlet beluga whale liver tissue compared well with samples of beluga whale liver from Point Lay and Point Hope, Alaska in the Chukchi Sea, where MeHg concentrations ranged between 0.37 to 2.01 µg/g wet weight. Becker (1995) also indicated that samples from all the above locations were similar to levels for beluga whales analyzed previously from the Eastern Beaufort Sea, Arctic Canada, and Greenland.

5.3 FDA Action Levels and EPA Criteria for Fish Tissue Mercury levels

The FDA action level for methylmercury in all fish is 1.0 µg/g, edible portion only, established in Sec 540.600 Compliance Policy Guidance (USFDA, 1998). The FDA term "fish" refers to fresh or saltwater fin fish, and other forms of aquatic animal life other than birds or mammals, and all mollusks, as defined in 21CRF 123.3(d). The term "action level" is the level at which FDA takes

and Saffron cod tissue levels collected to support this request, are substantially lower than the action levels and current EPA criteria.

Table 5-5
Results of FDA Fish Sampling for Methylmercury
for October 1990 to October 1991

Fish Species	Methylmercury (µg/g- wet weight)- Low	Methylmercury (µg/g -wet weight) - High
Bass, fresh water	0.15	0.34
Catfish, fresh and salt water	0.10	0.31
Cod	Trace	Trace
Crabs	0.10	0.15
Croaker	0.13	0.32
Flounder	ND	0.08
Grouper	0.35	0.48
Haddock	Trace	Trace
Lobster	0.10	0.14
Mackerel	0.10	0.23
Mahi mahi (dolphin)	0.11	0.21
Marlin	0.10	0.92
Orange Roughy	0.42	0.71
Oysters	Trace	0.10
Perch, fresh water	ND	0.31
Perch, salt water (rosefish, red rockfish)	Trace	0.03
Pike	Trace	0.16
Pollack	ND	0.10
Salmon	ND	0.11
Shrimp	Trace	0.10
Shark	0.23	2.95
Snapper, red	0.07	0.26
Swordfish	0.26	3.22
Trout	Trace	0.13
Tuna, canned	ND	0.75

Note:
ND = none detected
Trace = at detection limit

Table 5-6
FDA Guidance on Fish Consumption for Methylmercury

Fish Methylmercury Levels - Wet Weight	Consumer Category	Consumption Guidance
1.0 µg/g to >1.0 µg/g	Pregnant and lactating women	1 - 7 oz serving/ month
	Women of childbearing age who may become pregnant	1 - 7 oz serving/ month
	All others	1 - 7 oz serving/ week
0.5 µg/g	All persons	2 - 7 oz servings/ week
<0.2 µg/g	All persons	2.2 lbs./ week

Table 5-7		
Current US EPA Consumption and Tissue Concentrations Used as Regulatory Endpoints		
Criteria	Consumption Rate	Fish Tissue Concentration Wet Weight
US EPA National Criteria	6.5 g/day	1.1 µg/g
Great Lakes Initiative	15 g/day	0.5 µg/g
US EPA CA Toxics Rule	18.7 g/day	0.1 µg/g

5.4 Source of Bioconcentration in Fish

Migratory and resident fish were sampled in upper Cook Inlet during August and October 1998. Samples were analyzed for total mercury (THg) and methylmercury (MeHg). Details of the sampling and handling procedures are given in Appendix IV. The results of this sampling are shown in Tables 5-2 and 5-3. The results indicate low levels of MeHg in both the migratory Coho salmon tissue and the resident Saffron cod tissue with blank uncorrected averages of 0.0447 µg/g wet weight and 0.0519 µg/g wet weight, respectively.

The measured salmon and cod tissue levels from Cook Inlet compare well with the lowest tissue levels monitored by the FDA October 1990 to October 1991 (Table 5-5) of all commercial fish, that of ocean perch with measured MeHg tissue levels at 0.03 µg/g wet weight (Foulke, 1998). The same FDA study measured methylmercury in salmon at 0.11 µg/g wet weight (maximum). The Cook Inlet Coho salmon and Saffron cod compare favorably with the national average THg concentration of fish collected throughout the U.S. by the U.S. Fish and Wildlife Service of 0.10 µg/g wet weight (geometric mean), 0.37 µg/g wet weight (maximum), and 0.17 µg/g wet weight (85th percentile) (Schmitt and Brumbaugh, 1990 as cited in San Francisco Bay Regional Water Quality Control Board, 1998). The U.S. Fish and Wildlife data was based on a composite of 315 samples of whole fish from 109 stations nationwide in 1984. Comparison to these data indicates that upper Cook Inlet Coho salmon are well below levels of mercury found elsewhere in the U.S as do the upper Cook Inlet Saffron cod.

The accumulation of MeHg in fish is controlled by the total mercury concentration in the water, water temperature (the season), and trophic level (Korhonen et al., 1980). Typically in seawater, 100 % of MeHg is CH_3HgCl while only 3% of inorganic mercury is mercury chloride, $HgCl_2$ (Mason et al., 1980). Mason et al, (1980) calculated the bioaccumulation by plantivorous fish to be at least 16 times greater than the concentration of MeHg in the water. In freshwater systems, bioaccumulation depends on the speciation of Hg^{2+} and CH_3Hg^+. Mason et al., (1980) indicate the typical percentage of MeHg in CH_3HgCl is 0.5 to 1.5 times the percentage inorganic Hg in $HgCl_2$.

5.5 Human Health Risk Assessment

Fish may concentrate methymercury (MeHg) either directly through the water or through components of the food chain and MeHg has a long half-life in fish of about 2 years (Tollefson, 1989). MeHg

uptake by fish is first distributed to the tissue (primarily muscle) over a period of a few weeks, and then discharged from the binding sites very slowly. This slow release is one of the reasons fish are a major source of MeHg to humans. MeHg is highly bioavailable with 95 % absorption reported from the gastrointestinal tract of humans (Hrudley et al., 1996). The kinetics of methymercury have been summarized by Tollefson (1989). The half-life of MeHg in the adult human has been shown to be approximately 70 days. MeHg affects the central nervous system, primarily the sensory-motor system, resulting in hearing, tunnel vision, and altered sense of touch and pain (Malachowski, 1995). In adults, parenthesia is the lowest order clinical symptom and is a numbness and tingling sensation around the mouth, lips, fingers, and toes (Tollefson, 1989).

For adults and fetuses MeHg appears to be the most toxic for chronic exposure but there is conflicting information on the relationship between duration of exposure to MeHg and how best to incorporate duration of exposure into models to estimate threshold levels (Tollefson, 1989). Exposure assessments for MeHg have focused on the consumption of fish and shellfish as the important sources of MeHg for the majority of individuals. Bloom (1992) found that nearly 100% of Hg in fish tissue is in the methylated form. Therefore, many studies since then have monitored only for total Hg, which is analytically easier and includes the methylated form. Fish consumption studies have looked at populations that are high fish consumers such as subsistence fishing in Sweden, Peru, and American Samoa, where MeHg levels in blood and hair indicated that chronic exposure had occurred over many years with no signs or symptoms of ill effects (Tollefson, 1989).

Fish consumption patterns in the US have been found to have a large amount of variance depending on a number of factors including for example, the geographic location of the study participants (central states versus coastal states), the demographics of the study participants (urban versus rural), and the age of the study participants (infants versus elderly). The US EPA, *Exposure Factor Handbook* (1990) suggested an average value (50th percentile) of 30g/day and a worst case (90th percentile) of 140 g/day based on the data reported by Puffer (1981) and Pierce et al., (1981). To assess health risks these consumption levels need to be modified by an appropriate "dietary factor" accounting for the fraction of fish contaminated at a particular level. Other estimates of fish consumption (assumed contaminated at the associated level) are shown in Table 5-7, above.

In Alaska, the level of fish consumption for a given population is considered to be dependent on a variety of factors including regional setting, cultural factors, density of population (i.e. urban, rural), and purchased consumption versus subsistence consumption. For Alaska, ADEC (1998) has developed exposure scenarios using a regional classification system that reflects the predominant Alaska Native culture associated with major ecological regions. Anchorage and vicinity is classified as urban-urban periphery with a salmon consumption rate average and 50th percentile median of 32 g/day/person and a 95th percentile (high end) of 60 g/day/person. Both of these consumption rates are included in the following analysis for comparison to other consumption rates found in other urban areas or in high fish consumption populations.

The determination of exposure for a given person is contained in two equations as indicated in Tables 5-8 and 5-9, for determination of lifetime average daily exposure and maximum allowable daily fish consumption rates, respectively. Table 5-8 shows the variables necessary to calculate the lifetime average daily exposure in mg/kg-day. The most uncertain variables are fish consumption rate (CR),

exposure duration (ED), and diet fraction (DF). As explained in the notes section of Table 5-8 an average and worst-case value can be used for each variable. Table 5-9 can be used to estimate the consumption level needed to attain the reference dose for particular levels of fish tissue burden. The reference dose (RfD) for methylmercury is given by EPA (1997) as the noncarcinogen chronic value for both developmental and chronic systematic mercury with a value of 1×10^{-4} mg/kg/day.

The results are consistent with other available data for fish tissue in Cook Inlet recently collected during the Cook Inlet Contaminant Study conducted by EPA and presented in the Preliminary Findings (EPA, 1998). The EPA sampling was done near the mouth of the Cook Inlet (Seldovia, Port Graham, and Nanwalek) and at one station in upper Cook Inlet (Tyonek). Only Salmon (Chinook and Sockeye) were sampled at the Tyonek location and the results (preliminary findings) indicate methylmercury burdens are below the level of concern. Possible levels of concern for the EPA study were based on consumption limits greater than 12 (8-ounce) meals per month. This consumption limit was used by EPA as a preliminary guideline for analysis purposes and may change in subsequent analysis. Potential levels of concern were exceeded only for Sea Bass taken in the Port Graham sampling area. Table 5-4 summarizes the preliminary findings for salmon species collected in the EPA study.

Table 5-8 Calculation of Lifetime Average Daily Exposure [1]			
LADE = (CR * C * ED * DF)/(BW * LT)			
Var.	Description	Units	Notes
LADE	Lifetime Average Daily Exposure	mg/kg-day	
CR	Fish Consumption Rate	g/day [2]	Quantity of fish and shellfish (fresh and marine) consumed.
C	Concentration of contaminant in fish	mg/kg (µg/g)	Quantity of contaminant found in fish tissue. Site specific.
ED	Exposure duration	days	How long a person lives or visits the target area. EPA (1990) suggested the average exposure duration (or how long a person will live in one area) was 9 years (3285 days) and 30 years of (10,950 days) for reasonable worst-case estimates.
DF	Diet Fraction	unitless	Portion of a persons fish diet derived from the contaminated source. EPA (1991) suggests 20 percent as a reasonable value for fish derived from the target area.
BW	Body weight	kg	70 kg is average for an adult male and female (EPA 1985)
LT	Lifetime	days	Average life expectancy of men and women is 74.6 years (Bureau of the Census Statistical Abstract of the United States, 1985)
[1] EPA. 1990. *Exposure Factors Handbook*. EPA 600/8-89/043 [2] Value should be converted to kg/day for calculation			

Table 5-9
Daily Consumption Limits for Non Carcinogens[1]

$$CR_{lim} = (RfD*BW)/(C_m)$$

Var.	Description	Units	Notes
CR_{lim}	Maximum allowable daily fish consumption rate	kg/day	
RfD	Reference Dose	mg/kg-day	EPA (1997) lists the Noncarcinogen Chronic RfD value for both developmental and chronic systemic mercury (methylmercury) as 1×10^{-4} mg/kg/day
BW	Consumer Body weight	kg	70 kg is average for an adult male and female (EPA 1985
C_m	Measured concentration of chemical contaminant "m" in a given species of fish (mg/kg)	mg/kg (μg/g)	Quantity of contaminant found in fish tissue. Site specific
[1] EPA. 1990. *Exposure Factors Handbook*. EPA 600/8-89/043			

Table 5-10 shows the results of calculating the various worst-case scenarios using the fish tissue data collected in upper Cook Inlet. The calculations summarized in this table are based on the average concentration of the measured salmon tissue levels of MeHg. The calculations assume an exposure duration of an entire lifetime for an adult. The assumption is also made that all the fish consumed are upper Cook Inlet salmon (dietary factor of 1). The calculations are done for a the range of consumption rates following those discussed above. In addition, the calculation of the daily consumption limit required to achieve the reference dose of 0.0001 mg/kg/day is shown in the last row of the calculations. Consumption of 159.5 grams of upper Cook Inlet salmon per day is required to reach the defined level of concern. This is substantially higher than the level EPA used in the Cook Inlet Contaminant Study (12-8 oz. meals/month = 91 g/day).

For any particular area, region, or population, the calculation of LDAE is based on assumptions concerning the availability and consumption of fish. In the area proposed for SSWQC the fisheries resources utilized are generally limited to salmon and commercial salmon harvest is conducted primarily in lower Cook Inlet and portions of upper Cook Inlet outside of Knik Arm and the immediate vicinity (CH2M HILL, 1998). There is an educational fishery in Knik Arm that teaches native fishing methods. However, this only occurs annually with a relatively small catch (a few hundred fish). The closest potential known subsistence fishery is at Tyonek, approximately 50 to 60 miles down the inlet (toward the ocean) from the proposed area for SSWQC. The consumption level used by EPA in the Cook Inlet Contaminant Study: Preliminary Findings (1998) is considered appropriate for the analysis conducted above.

5.6 Recommended Site Specific Criteria for Mercury

As described in the review of the sources and biogeochemistry of mercury (Section 5.1), conditions in upper Cook Inlet are not conducive to extensive mercury methylation. This suggests that the background dissolved mercury concentration in Cook Inlet represents all the background mercury that is available for methylation, and the non-dissolved fraction is not bioavailable. The relatively low levels of fish tissue methylmercury are consistent with, and qualitatively support, this conclusion.

Table 5-10
Calculation of MeHg Exposure for Consumption of Cook Inlet Salmon

Fish Consumption Rate (g/day)	Concentration of MeHg in Fish [1] (µg/g - wet weight)	Exposure Duration [2] (days)	Diet Fraction [3]	Body Weight [4] (kg)	Lifetime (days)	Lifetime Average Daily Exposure (mg/kg/day)
6.5	0.045	27,393	1	70	27,393	0.000004
15	0.045	27,393	1	70	27,393	0.000010
18.7	0.045	27,393	1	70	27,393	0.000012
30	0.045	27,393	1	70	27,393	0.000019
32 [5]	0.045	27,393	1	70	27,393	0.000021
60 [6]	0.045	27,393	1	70	27,393	0.000039
91	0.045	27,393	1	70	27,393	0.000059
140	0.045	27,393	1	70	27,393	0.000090
159.5 [7]	0.045	27,393	1	70	27,393	0.000103

1 Average MeHg concentration for Coho salmon measured for upper Cook Inlet
2 Entire lifetime lived in upper Cook Inlet area
3 All fish consumed with measured levels of MeHg
4 Average adult
5 ADEC (1998) consumption rate for urban-urban periphery area of Anchorage (average and 50 th percentile, median value)
6 ADEC (1998) consumption rate for urban-urban periphery area of Anchorage (95 th percentile, high end value)
7 Consumption required to achieve EPA defined health based reference dose

Based on the data and discussions provided above, and in Section 4, a site specific criteria for mercury, consistent with that proposed for other metals, would protect marine life and human health to the same degree as the current criteria. For mercury it is proposed that the SSWQC be as follows:

- Criteria Maximum Concentration (acute) be set at 1.8 µg/l for dissolved fraction, which is consistent with EPA Metals Policy

- Criteria Continuous Concentration (chronic) be set at 0.025 µg/l for the dissolved fraction, which actually is based on protection of human health consistent with the discussions above, and is lower than required for the protection of aquatic life or other beneficial uses

The levels of mercury proposed are for the dissolved fraction because the non-dissolved fraction in the background water is considered non-bioavailable and associated with mineral particulates The justification for the mercury criteria is summarized as follows:

- The non-dissolved fraction of mercury in the background receiving water appears to be associated with mineralized sediment particles generated by glacial weathering of rock and introduced into the receiving water by the river discharges

- The non-dissolved mercury fraction associated with the sediment loads from the river is essentially unavailable for conversion to methylmercury or dissolved organic mercury, and therefore ultimately not bioavailable

- Fishing in the proposed area for SSWQC is limited to commercial salmon. The mercury levels in the salmon as well as the resident cod species appear to be well below the most restrictive regulatory endpoint applied

- The closest subsistence fishery is in the Tyonek area, west of the proposed area for SSWQC

- Both the recent EPA analysis (Cook Inlet Contaminant Study; Preliminary Findings, 1998) and the preliminary human health risk assessment presented above indicate that the levels of mercury found in salmon are below levels of concern, even with high assumptions concerning consumption levels

- Based on the fish tissue levels, the conclusion that the high non-dissolved background levels are not bioavailable appears to be supported, and is not reflected in the tissue levels

Table 4-3 includes the proposed SSWQC for mercury and the proposed area for application of the SSWQC is that shown in Figure 1-2. The criteria proposed for mercury is similar to other metals as it is based on the dissolved fraction for the reasons documented above.

The recommended SSWQC for mercury presented above were based on a scientifically defensible approach. The approach used considers the unique characteristics of the upper Cook Inlet, the bioavailability of the various fractions of mercury in the water column, fish tissue burdens, and human health considerations. The recommended SSWQC are based on dissolved mercury since the non-dissolved fraction is not bioavailable. An alternative approach using the total recoverable fraction of mercury could be developed. Such an approach would be to calculate SSWQC based on site specific observed water column and fish tissue burdens. The fish tissues burdens for salmon, the only species commonly consumed by humans, were 0.045 µg/g, the 50th percentile total recoverable mercury concentration in the water body is 0.04 µg/l (equivalent to approximately 0.00004 µg/g). Based on these values the apparent bioconcentration factor (BCF) would be 1000:1. The EPA water quality criteria (0.025 µg/l) is based on a BCF of 25,000:1. Therefore, the appropriate SSWQC for total recoverable mercury would be 0.625 µg/l. This value reflects the fact that the non-dissolved fraction is not bioavailable.
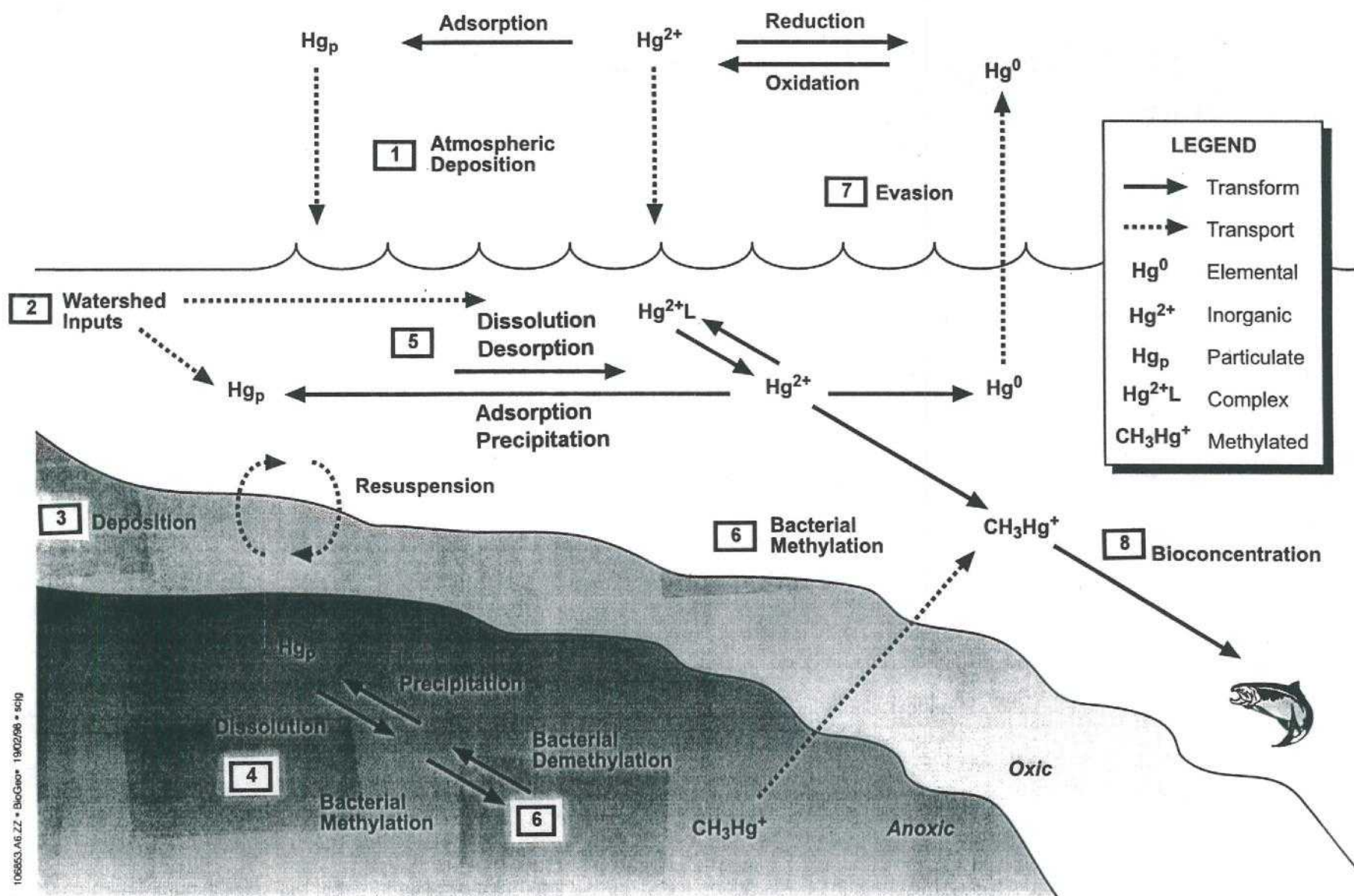
Figure 5-1
Mercury Biogeochemical Cycling Pathways

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Appendix I

Point Woronzof Discharge:

Background and Compliance Issues

Appendix I

Point Woronzof Discharge: Background and Compliance Issues

This appendix provides information on the major anthropogenic input to the area requested for application of SWWQC. A description of the discharge and its relationship to the SSWQC request, a review of the loadings from this discharge, and an analysis of the potential for compliance with the proposed SSWQC are discussed below. The material presented indicates that the discharge will comply with the proposed SSWQC.

I.1 Background and Description

The Municipality of Anchorage's Pt. Woronzof WWTP serves the Anchorage area and primarily treats domestic sewage with a small industrial component. The facility provides primary treatment for maximum design flows of 58 mgd and 154 mgd average and maximum hourly, respectively. The maximum daily flow projected for the year 2005, the end of the current permit renewal period, is 44 mgd.

The effluent is discharged under the NPDES permit issued in 1985. Permit renewal and 301(h)waiver applications were submitted in 1990 and 1998. The 1985 permit, however, was not reissued and remains in effect. The WWTP anticipates additional influent stream(s) from new seafood processing plant(s). It is anticipated that the existing limits for the discharge of BOD will not be sufficient to account for the expected influent conditions. Therefore, the Municipality of Anchorage has prepared, and is in the process of submitting, a new application for renewal of the NPDES permit and a 301(h) waiver application.

The assimilate capacity of the receiving waters for the requested increased BOD limits is not in question. There is substantially more capacity in the receiving waters than required, and the increased loads will have a negligible effect on dissolved oxygen. However, the existing permit limits for metals and turbidity are based only on discharge concentrations, whereas the existing Alaska water Quality Standards (ADEC, 1997) are water-quality based and require the consideration of receiving water concentrations. For the reasons described in the SSWQC request, there is no assimilative capacity for turbidity and certain metals. The issuance of a renewal permit depends on the establishment of SSWQC.

I.2 Review of Effluent Loading

Effluent metals in the Point Woronzof discharge, as dissolved and total recoverable, were measured during the receiving water monitoring studies conducted annually, generally during early August. Samples were collected and analyzed for dissolved and total recoverable metals in the effluent, at three points in the vicinity of the Point Woronzof discharge, and at three background or control locations near Point MacKenzie. The results from 1991 through 1997 are used in this section of the report. Detailed tabulations are provided in Appendix II. The results for the effluent samples are

given in Table I-1. Concentrations found in the receiving water are described in Sections 2.1 and 2.2 of the SSWQC request document.

Table I-1 presents the dissolved and total recoverable fractions of each of the metals listed. The maximum, minimum, and mean values include the detection limits for those samples that were indicated as below detection. (Note: a change in methodology in selenium analysis reduced detection limits for the 1997 samples, see Appendix II for detailed compilation, and the 99th percentile of the total recoverable column includes only those samples above detection limits.) The 99th percentile values were calculated based on a log-normal distribution following EPA (1991).

		Dissolved			Total Recoverable			
		Maximum	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**99th percentile**
Arsenic	µg/l	3.860	<0.420	<1.933	2.900	1.160	1.943	5
Cadmium	µg/l	0.251	0.057	0.137	0.481	0.207	0.334	0.6
Chromium	µg/l	0.979	0.236	0.465	13.200	2.700	6.033	20
Copper	µg/l	33.90	8.410	25.439	45.20	23.80	37.657	60
Lead	µg/l	1.090	0.130	0.464	6.80	2.49	3.85	9
Mercury	µg/l	0.022	0.00035	0.0064	0.116	0.050	0.092	180
Nickel	µg/l	2.2	0.57	1.45	2.71	1.20	2.09	4.2
Selenium	µg/l	<2.900	0.443	<1.304	<7.24	0.643	<2.737	0.6
Silver	µg/l	2.970	0.141	0.718	9.050	4.390	6.589	14
Zinc	µg/l	68.50	19.40	37.275	480.0	42.60	137.257	613

Table I-1
Effluent Metals Concentrations

The effluent has not been monitored for turbidity but total suspended solids (TSS) and settleable matter is routinely measured. Settleable matter in the effluent is routinely below the detection limit of 0.1 mg/l. For the calendar year 1997 the measured values of TSS indicated a maximum monthly average of 53 mg/l and an annual average of 48 mg/l. Measurements of effluent TSS concurrent with receiving water TSS and turbidity were done in 1996 and 1997. Effluent TSS was 60 mg/l and 42 mg/l for 1996 and 1997, respectively. Receiving water levels were 3 to 36 times higher.

I.3 Compliance With Proposed SSWQC

Turbidity has not been measured in the Point Woronzof effluent, but TSS is measured and has also recently been measured in the background as described in Section 2 of the SSWQC request document. As described in the SSWQC request, there is a strong correlation between turbidity and TSS, since the high values of turbidity are a result of the high riverine TSS loadings. Natural levels of TSS in the receiving water appear to be an order of magnitude higher than TSS in the discharge. The discharge is not expected to cause an increase in TSS (or turbidity), but will generally lower the level of natural turbidity in the vicinity of the discharge. Therefore, compliance with the requested SSWQC for turbidity will be attained.

Table I-2 shows 95th percentile of the measured (1991 through 1997) dissolved and total recoverable background concentrations of metals and the 99th percentile of the measured (total recoverable) effluent concentrations for metals. Background concentrations are from the Point MacKenzie sampling stations. The table also shows the concentration of the discharge total recoverable concentrations after initial dilution based on using the dissolved background to account for effective dilution. This procedure incorporates the SSWQC based on the dissolved fraction and assuming a translator between total recoverable and dissolved fractions of 1 for the effluent. The use of a translator of 1 recognizes that the total recoverable metal fraction in the effluent discharge may be potentially bioavailable. This approach is somewhat more conservative than the EPA Metals Policy approach for dissolved metals. These values for effluent concentrations after initial dilution can then be compared to the AWQS for total recoverable metals and the EPA Interim Final Rule dissolved criteria, which are also presented in the table.

Table I-2 Measured Effluent and Background Concentrations, Existing AWQS, and EPA Interim Final Rule Dissolved Criteria for Metals (based on criteria continuous concentration (chronic) levels)						
Metal		Background 95th Percentile		Effluent (Total Recoverable) 99th Percentile		AWQS	EPA Dissolved Criteria
		Total Recoverable	Dissolved	As Discharged	After Initial Dilution [1]		
Arsenic	µg/l	32.4	1.88	5	1.89	36	36
Cadmium	µg/l	0.435	0.056	0.6	0.059	9.3	9.3
Chromium	µg/l	117.0	0.790	20	0.90	50	50
Copper	µg/l	54.7	0.89	60	1.2	2.9 [2]	3.1
Lead	µg/l	10.7	0.13	0	0.13	5.6	8.1
Mercury	µg/l	0.119	0.00605	0.18	0.007	0.025	None [3]
Nickel	µg/l	38.5	1.37	4.2	1.4	7.1 (8.3) [4]	8.2
Selenium	µg/l	0.623	0.122	0.6	0.12	none (71) [4]	71
Silver	µg/l	0.38	0.107	14	0.18	2.3 [2]	1.9 [2]
Zinc	µg/l	1240	2.35	613	5.7	58 (86) [4]	81

[1] Based on dilution calculated with dissolved concentrations in the background.
[2] The silver criteria and AWQS copper criterion are acute rather than chronic
[3] Mercury criteria should be based on protection of human health described in Section 5 of the SSWQC request, EPA's California toxic rule levels for CCC are 0.94 µg/l as dissolved and the human health criterion is 0.51 µg/l as total recoverable.
[4] Criteria in parentheses are ADEC proposed revisions to the existing total recoverable criteria.

As shown in Table I-2 the background chromium, copper, lead, mercury, nickel, and zinc total recoverable background concentrations are above the AWQS criteria and there is no assimilative capacity in the receiving waters for the Point Woronzof discharge. The SSWQC request proposes the use of the EPA dissolved criteria for all metals except mercury. Mercury criteria must be based on human health considerations no dissolved criterion is shown in the table. A criteria for mercury based

on human health of 0.025 µg/l for the dissolved fraction is proposed in the SSWQC request document.

As discussed in Section 2 of the SSWQC request document, the non-dissolved fraction of the metals in upper Cook Inlet is associated with mineral particles introduced by riverine input of glacially scoured rock and is not considered bioavailable. The proposed NPDES permit limitations, presented in the permit renewal application, would base compliance for the discharge on the total recoverable metal in the effluent (translator =1) but using the dissolved background value. The proposed approach, using dissolved background and total recoverable discharge concentrations, is reflected in the calculation for concentration after initial dilution in Table I-2. The results in Table I-2 show that the discharge would be in compliance with the proposed SSWQC.

The obvious alternative to setting SSWQC for the vicinity of Pt. Woronzof is advanced treatment and metals removal from the waste stream. To achieve metals removal it would first be necessary to provide secondary and tertiary treatment to obtain effluent that could then be subjected to metals removal. It is noted that simply upgrading treatment level would have little or no effect on metals concentrations with out additional specific metals removal process. As an example, the typical metals concentrations found in secondary municipal waste water treatment effluent, compared to the levels currently found in the Point Woronzof effluent, is shown in Table I-3. Metals removal would require application of membrane technology following treatment upgrades. Preliminary cost estimates for metals removal indicates that the cost of such increased levels of treatment is approximately 500 million dollars. Metals removal as an alternative is not considered feasible or necessary.

Table I-3 Metals Concentrations in Secondary Effluents Compared to Point Woronzof Effluent (µg/l)				
	Range In Secondary Effluent	Range in Point Woronzof Effluent		
		1st percentile	50th percentile	99th percentile
As	1-72	0.6	1.7	4.9
Cd	2-82	0.16	0.32	0.65
Cr	2-759	1.5	5.5	19.8
Cu	3-255	22.8	37.0	60.2
Pb	20-217	1.5	3.6	8.7
Hg	0.2-1	0.04312	0.08836	0.18107
Ni	7-679	0.9	2.0	4.3
Se	1-150	0.643	0.643	0.643
Ag	1-30	2.9	6.3	13.6
Zn	18-3150	16	98	613
EPA, 1992. Fate of Priority Pollutants in Publicly Owned Treatment Works. Final Report, Volume 1, EPA 440/1-82/303 Effluent Guidelines Division, WH-552.				

Previous modeling of Cook Inlet (Tetra Tech, 1979) indicates that the long term steady state concentration of conservative substances of any discharge at Pt. Woronzof is on the order 0.001 of the discharged concentration (dilution on the order of 1000:1) at the open boundaries of the area

considered. This prediction is based on the anticipated discharge rate from the Pt. Woronzof WWTP in the year 2005 as described in the NPDES Permit renewal application (CH2M HILL,1998), and indicates that the effect of the discharge at the boundaries of the proposed area, compared to the background levels, would be negligible.

Appendix II

Metals Concentrations in

Point Woronzof Discharge and Receiving Water

Table II-1
Receiving Water Monitoring for Arsenic [As] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	NA	NA	NA	NA	NA	NA	NA	NA	07-Aug-91	NA	NA	NA	NA	NA	NA
12-Aug-92	NA	NA	NA	NA	NA	NA	NA	NA	13-Aug-92	NA	NA	NA	NA	NA	NA
05-Aug-93	3.11	1.17	2.02	10.3	1.87	5.25	1.71	5.06	04-Aug-93	1.24	8.36	1.40	27.0	1.40	24.3
15-Aug-94	0.42	1.25	3.11	6.23	1.84	17.8	2.12	2.68	16-Aug-94	1.98	6.05	1.84	3.75	1.84	10.2
09-Aug-95	1.37	2.9	1.46	10.2	1.64	17.2	1.64	5.1	08-Aug-95	1.73	18.5	1.64	30.6	1.55	37.8
06-Aug-96	3.86	2.63	1.35	12.0	1.21	11.9	1.19	8.38	07-Aug-96	0.98	7.47	1.04	9.33	1.20	11.0
05-Aug-97	0.905	1.16	1.29	9.82	1.11	9.99	1.15	17.00	06-Aug-97	1.07	13.5	1.04	2.83	1.08	7.91

Grouped:	EFFLUENT		Grouped:	PT. WORONZOF		Grouped:	PT. MACKENZIE	
Minimum	0.42	1.2	Minimum	1.110	2.68	Minimum	0.980	2.83
Maximum	3.86	2.9	Maximum	3.110	17.80	Maximum	1.980	37.80
Average	1.93	1.8	Average	1.647	9.93	Average	1.402	14.57
X_{99}	11.94	4.9	X_{95}	2.37	17.35	X_{95}	1.88	32.40
X_{50}	1.44	1.7	X_{50}	1.64	9.99	X_{50}	1.40	10.20
X_1	0.17	0.6	X_5	1.14	4.46	X_5	1.03	3.52

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

<table>

Table II-3
Receiving Water Monitoring for Chromium [Cr] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	0.42	4.80	0.18	88.0	0.18	25.6	0.18	7.20	07-Aug-91	0.18	80.8	0.12	37.6	0.18	36.0
12-Aug-92	0.26	13.2	0.19	70.3	0.22	91.4	0.16	18.4	13-Aug-92	0.13	58.5	0.38	83.5	0.19	86.1
05-Aug-93	0.25	8.36	0.16	25.4	**0.05**	24.4	0.25	7.97	04-Aug-93	0.06	33.3	0.79	56.7	0.09	59.2
15-Aug-94	0.56	3.32	0.22	29.8	0.19	54.2	0.28	3.87	16-Aug-94	0.42	14.9	0.47	45.4	0.25	30.4
09-Aug-95	0.236	7.00	0.307	43.2	0.213	59.3	0.142	28.1	08-Aug-95	0.166	55.8	0.166	117	0.189	152
06-Aug-96	0.979	4.55	0.511	30.7	0.433	33.7	0.396	20.9	07-Aug-96	0.410	19.9	0.435	25.5	0.464	31.0
05-Aug-97	0.552	2.70	0.261	23.5	0.243	24.4	0.251	39.7	06-Aug-97	0.829	31.5	0.236	5.23	0.271	17.5

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF						Grouped:	PT. MACKENZIE	
Minimum	0.24	2.7		Minimum	0.05	3.9					Minimum	0.06	5
Maximum	0.98	13.2		Maximum	0.51	91.4					Maximum	0.83	152
Average	0.47	6.3		Average	0.24	35.7					Average	0.31	51
X_{99}	1.42	19.8		X_{95}	0.43	88.0					X_{95}	0.79	117
X_{50}	0.41	5.5		X_{50}	0.22	28.1					X_{50}	0.24	38
X_1	0.12	1.5		X_5	0.14	7.2					X_5	0.09	15

</table>

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

Table II-4
Receiving Water Monitoring for Copper [Cu] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	27.0	45.2	0.91	28.7	3.52	29.7	1.35	5.90	07-Aug-91	0.85	23.1	0.68	30.1	0.68	26.7
12-Aug-92	8.41	36.1	1.00	14.7	1.39	15.8	1.15	9.85	13-Aug-92	0.96	11.0	0.77	12.5	0.80	18.0
05-Aug-93	28.1	23.8	0.59	34.2	1.28	17.3	7.56	14.0	04-Aug-93	0.68	31.1	0.64	29.8	0.50	29.3
15-Aug-94	33.9	40.3	2.28	31.1	0.85	55.8	1.27	3.25	16-Aug-94	0.893	10.6	0.805	42.0	0.699	26.7
09-Aug-95	22.0	37.6	0.816	27.1	0.758	44.9	1.25	6.24	08-Aug-95	0.632	35.6	0.658	54.7	0.602	70.6
06-Aug-96	29.0	42.1	3.15	30.0	0.983	34.8	1.40	21.1	07-Aug-96	0.826	17.1	0.736	21.4	0.744	25.7
05-Aug-97	28.2	38.5	2.92	29.1	0.709	26.9	0.630	48.2	06-Aug-97	0.659	38.3	0.468	5.83	0.502	20.5

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF						Grouped:	PT. MACKENZIE	
Minimum	8.4	23.8		Minimum	0.59	3.3					Minimum	0.47	5.8
Maximum	33.9	45.2		Maximum	7.56	55.8					Maximum	0.96	70.6
Average	25.2	37.65714286		Average	1.70	25.2					Average	0.70	27.6
X_{99}	69.9	60.2		X_{95}	3.52	48.2					X_{95}	0.89	54.7
X_{50}	23.4	37.0		X_{50}	1.25	27.1					X_{50}	0.68	26.7
X_1	7.9	22.8		X_5	0.63	5.9					X_5	0.50	10.6

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

Table II-5
Receiving Water Monitoring for Lead [Pb] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	0.430	6.80	**0.035**	0.859	**0.035**	10.8	**0.035**	1.68	07-Aug-91	**0.035**	0.655	**0.035**	0.941	**0.035**	6.40
12-Aug-92	0.13	2.49	0.04	1.59	0.03	0.98	**0.023**	1.89	13-Aug-92	0.13	0.98	**0.023**	0.75	0.19	0.79
05-Aug-93	0.59	2.6	0.006	7.6	0.014	3.8	0.012	3.1	04-Aug-93	0.003	6.1	0.040	4.8	0.028	4.0
15-Aug-94	0.780	2.69	0.014	8.01	0.015	14.25	0.051	0.436	16-Aug-94	0.033	2.6	0.023	10.72	0.015	6.88
09-Aug-95	0.293	3.32	0.024	5.95	0.019	9.33	0.026	1.16	08-Aug-95	0.018	7.10	0.018	6.35	0.018	12.3
06-Aug-96	0.207	3.96	0.089	6.41	0.019	7.74	0.015	4.97	07-Aug-96	0.016	3.65	0.028	4.63	0.031	5.65
05-Aug-97	1.09	5.09	0.114	7.35	*0.0187*	6.95	*0.0138*	12.6	06-Aug-97	*0.0192*	9.83	*0.0114*	1.38	*0.0099*	5.02

Grouped:	EFFLUENT		Grouped:	PT. WORONZOF			Grouped:	PT. MACKENZIE	
Minimum	0.13	2.5	Minimum	0.01	0.4		Minimum	0.00	0.7
Maximum	1.09	6.8	Maximum	0.11	14.3		Maximum	0.19	12.3
Average	0.50	3.9	Average	0.03	5.6		Average	0.04	4.8
X_{99}	2.32	8.7	X_{95}	0.09	12.6		X_{95}	0.13	10.7
X_{50}	0.40	3.6	X_{50}	0.02	6.0		X_{50}	0.02	4.8
X_1	0.07	1.5	X_5	0.01	0.9		X_5	0.01	0.8

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

Bold Italic = Reported Value Below Detection Limit

$X_{\#\#}$ = The ## percentile

Table II-7
Receiving Water Monitoring for Nickel [Ni] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	1.59	2.60	0.98	4.46	0.95	27.4	0.89	4.96	07-Aug-91	0.77	5.99	0.77	7.84	0.78	19.7
12-Aug-92	0.57	1.46	1.57	4.86	1.63	1.66	1.24	9.92	13-Aug-92	1.50	3.51	1.24	2.63	1.29	2.51
05-Aug-93	1.1	1.2	0.64	30	0.99	16	0.69	12	04-Aug-93	0.57	24	0.60	15	0.68	13
15-Aug-94	1.95	2.24	0.772	26.3	0.648	45.7	0.938	3.01	16-Aug-94	1.17	10.0	1.37	38.5	0.657	23.6
09-Aug-95	0.988	1.75	0.916	19.7	0.683	30.5	0.733	4.10	08-Aug-95	0.608	26.7	0.656	29.2	0.638	49.6
06-Aug-96	1.67	2.65	1.07	24.1	1.13	29.7	1.04	17.2	07-Aug-96	1.02	14.4	1.05	18.0	0.997	22.0
05-Aug-97	2.20	2.71	0.826	23.0	0.784	22.6	0.830	40.1	06-Aug-97	0.973	31.5	0.562	5.05	0.571	17.1

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF				Grouped:	PT. MACKENZIE	
Minimum	0.6	1.2		Minimum	0.64	2			Minimum	0.56	3
Maximum	2.2	2.7		Maximum	1.63	46			Maximum	1.50	50
Average	1.4	2.1		Average	0.95	19			Average	0.88	18
X_{99}	3.9	4.3		X_{95}	1.57	40			X_{95}	1.37	39
X_{50}	1.3	2.0		X_{50}	0.92	20			X_{50}	0.77	17
X_{1}	0.4	0.9		X_{5}	0.65	3			X_{5}	0.57	3

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

Table II-8
Receiving Water Monitoring for Selenium [Se] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	NA	NA	NA	NA	NA	NA	NA	NA	07-Aug-91	NA	NA	NA	NA	NA	NA
12-Aug-92	NA	NA	NA	NA	NA	NA	NA	NA	13-Aug-92	NA	NA	NA	NA	NA	NA
05-Aug-93									04-Aug-93						
15-Aug-94									16-Aug-94						
09-Aug-95									08-Aug-95						
06-Aug-96									07-Aug-96						
05-Aug-97	0.443	0.643	*0.144*	0.505	*0.149*	0.502	*0.131*	0.830	06-Aug-97	0.110	0.623	*0.122*	0.168	*0.111*	0.394

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF					Grouped:	PT. MACKENZIE	
Minimum	0.443	0.643		Minimum	0.131	0.502				Minimum	0.110	0.168
Maximum	0.443	0.643		Maximum	0.149	0.830				Maximum	0.122	0.623
Average	0.443	0.643		Average	0.141	0.612				Average	0.114	0.395
X_{99}	0.443	0.643		X_{95}	0.149	0.830				X_{95}	0.122	0.623
X_{50}	0.443	0.643		X_{50}	0.144	0.505				X_{50}	0.111	0.394
X_1	0.443	0.643		X_5	0.131	0.502				X_5	0.110	0.168

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

Table II-9
Receiving Water Monitoring for Silver [Ag] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	0.851	4.39	0.005	0.088	0.008	0.473	0.004	0.028	07-Aug-91	0.002	0.073	0.002	0.081	0.001	0.054
12-Aug-92	0.141	8.81	0.004	0.099	0.008	0.158	0.009	0.058	13-Aug-92	0.014	0.102	0.003	0.145	0.003	0.121
05-Aug-93	0.67	8.9	0.005	0.51	0.011	0.57	0.006	0.31	04-Aug-93	0.002	0.40	0.008	0.24	0.013	0.25
15-Aug-94	2.97	9.05	0.113	0.302	0.044	0.163	0.029	0.071	16-Aug-94	0.007	0.043	0.073	0.127	0.107	0.197
09-Aug-95	0.285	5.36	0.249	0.078	0.004	0.124	0.008	0.029	08-Aug-95	0.005	0.107	0.003	0.126	0.003	0.176
06-Aug-96	0.221	4.71	0.016	0.375	0.023	0.069	0.017	0.063	07-Aug-96	0.11	0.031	0.014	0.38	0.021	0.048
05-Aug-97	0.399	4.90	0.132	0.031	0.040	0.025	0.023	0.009	06-Aug-97	0.017	0.011	0.020	0.025	0.017	0.009

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF					Grouped:	PT. MACKENZIE	
Minimum	0.14	4.4		Minimum	0.004	0.01				Minimum	0.001	0.01
Maximum	2.97	9.1		Maximum	0.249	0.57				Maximum	0.110	0.40
Average	0.79	6.6		Average	0.036	0.17				Average	0.021	0.13
X_{99}	5.09	13.6		X_{95}	0.132	0.51				X_{95}	0.107	0.38
X_{50}	0.48	6.3		X_{50}	0.011	0.09				X_{50}	0.008	0.11
X_{1}	0.05	2.9		X_{5}	0.004	0.03				X_{5}	0.002	0.01

NA = Not Applicable / Available
Bold = Value Below Detection Limit, Detection Limit Reported.
Bold Italic = Reported Value Below Detection Limit
$X_{\#\#}$ = The ## percentile

Table II-10
Receiving Water Monitoring for Zinc [Zn] (µg/L)

DATE	EFFLUENT		PT. WORONZOF-1		PT. WORONZOF-2		PT. WORONZOF-3		DATE	PT. MACKENZIE-1		PT. MACKENZIE-2		PT. MACKENZIE-3	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable		Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
08-Aug-91	25.0	118	0.64	292	1.73	128	0.55	32.0	07-Aug-91	0.73	166	0.55	155	0.64	103
12-Aug-92	68.5	54.3	0.70	72.3	0.93	151	0.93	19.4	13-Aug-92	0.81	54.3	0.70	90.4	0.46	127
05-Aug-93	30.7	480	0.53	661	1.73	302	0.80	272	04-Aug-93	0.40	191	**0.2**	1390	**0.2**	1240
15-Aug-94	44.6	107	3.11	105	0.88	169	1.65	14.6	16-Aug-94	1.95	48.6	0.97	134	0.78	106
09-Aug-95	55.2	87.5	1.95	137	1.76	162	3.80	18.7	08-Aug-95	2.22	180	2.13	255	1.48	329
06-Aug-96	27.1	71.4	2.71	59.7	0.76	89.2	1.10	42.5	07-Aug-96	0.93	34.5	0.68	59.7	0.51	68.9
05-Aug-97	19.4	42.6	2.91	54.9	2.30	52.1	1.82	88.7	06-Aug-97	83.7	72.1	2.35	12.8	2.04	71.6

Grouped:	EFFLUENT			Grouped:	PT. WORONZOF							PT. MACKENZIE		
Minimum	19.4	43		Minimum	0.53	14.6						0.2	13	
Maximum	68.5	480		Maximum	3.80	661.0						83.7	1390	
Average	38.6	137		Average	1.59	139.2						5.0	233	
X_{99}	102.5	613		X_{95}	3.11	302.0						2.4	1240	
X_{50}	35.3	98		X_{50}	1.65	89.2						0.8	106	
X_{1}	12.1	16		X_{5}	0.55	18.7						0.2	35	

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

Bold Italic = Reported Value Below Detection Limit

$X_{\#\#}$ = The ## percentile

Appendix III

Metals Concentrations in Rivers

Table III-1
River Water Sampling for Arsenic [As] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	0.258	5.59	0.543	10.1	0.764	2.23	0.678	17.5
19-Aug-98	0.298	3.11	0.600	6.42	0.579	3.06	0.699	12.0
25-Aug-98	0.955	1.74	0.645	5.38	0.750	2.24	0.993	7.36

Grouped:	All Rivers	
Minimum	0.258	1.7
Maximum	0.993	17.5
Average	0.647	6.4
X_{95}	1.184	16.8
X_{50}	0.605	5.0
X_5	0.309	1.5

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-2
River Water Sampling for Cadmium [Cd] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	0.195
19-Aug-98	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	0.0954
25-Aug-98	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**	**0.0786**

Grouped:	All Rivers	
Minimum	0.0786	0.079
Maximum	0.0786	0.195
Average	0.0786	0.090
X_{95}	0.0786	0.133
X_{50}	0.0786	0.086
X_5	0.0786	0.056

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-3
River Water Sampling for Chromium [Cr] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.0930**	16.9	**0.0930**	17.2	**0.0930**	0.433	**0.0930**	28.8
19-Aug-98	**0.0930**	8.81	**0.0930**	12.7	0.236	1.33	**0.0930**	17.6
25-Aug-98	**0.0930**	4.61	**0.0930**	11.2	**0.0930**	0.575	0.254	10.8

Grouped:	All Rivers	
Minimum	0.093	0.4
Maximum	0.254	28.8
Average	0.118	10.9
X_{95}	0.203	63.1
X_{50}	0.109	6.2
X_5	0.059	0.6

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-4
River Water Sampling for Copper [Cu] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.203**	15.4	**0.203**	22.3	0.566	2.27	0.369	68.7
19-Aug-98	0.236	8.70	**0.203**	14.5	0.844	6.35	0.257	25.9
25-Aug-98	0.354	4.22	0.220	12.7	0.771	2.69	0.361	15.8

Grouped:	All Rivers	
Minimum	0.203	2.3
Maximum	0.844	68.7
Average	0.382	16.6
X_{95}	0.785	54.6
X_{50}	0.334	10.8
X_5	0.142	2.1

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-5 River Water Sampling for Lead [Pb] (µg/L)								
DATE	**Eagle River**		**Knik River**		**Little Susititna River**		**Matanuska**	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.0336**	4.33	**0.0336**	7.17	**0.0336**	0.228	**0.0336**	13.5
19-Aug-98	**0.0336**	2.39	**0.0336**	4.35	**0.0336**	0.529	**0.0336**	8.01
25-Aug-98	0.0496	1.22	**0.0336**	4.02	0.0351	0.258	0.0379	4.62

Grouped:	**All Rivers**	
Minimum	0.0336	0.2
Maximum	0.0496	13.5
Average	0.0354	4.2
X_{95}	0.042	21.7
X_{50}	0.035	2.3
X_5	0.029	0.2

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	0.000499	0.0555	0.000405	0.0540	0.000941	0.00384	0.000408	0.00375
19-Aug-98	0.000496	0.0322	0.000589	0.0333	0.00162	0.0115	0.000463	0.0364
25-Aug-98	0.000330	0.0161	0.000560	0.0311	0.000906	0.00431	0.000851	0.0197

Table III-6(A)
River Water Sampling for Mercury [Hg] (Total) (µg/L)

Grouped:	All Rivers	
Minimum	0.00033	0.0038
Maximum	0.00162	0.0555
Average	0.00067	0.0251
X_{95}	0.00128	0.0912
X_{50}	0.00061	0.0175
X_5	0.00029	0.0034

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-6(B)
River Water Sampling for Methyl Mercury [MeHg] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	0.0000220	0.000123	*0.000034*	0.0000289	0.0000821	0.000142	0.0000129	0.000101
19-Aug-98	0.0000576	0.0000468	*0.000034*	0.0000715	0.000169	0.000177	*0.000034*	0.0000344
25-Aug-98	*0.0000344*	*0.0000344*	*0.000034*	*0.0000344*	0.0000487	0.0000955	*0.000034*	*0.0000344*

Grouped:	All Rivers	
Minimum	0.000013	0.000029
Maximum	0.000169	0.000177
Average	0.000050	0.000077
X_{95}	0.000116	0.000186
X_{50}	0.000040	0.000063
X_5	0.000014	0.000021

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-7
River Water Sampling for Nickel [Ni] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.225**	15.9	0.264	17.9	**0.225**	0.604	0.604	42.1
19-Aug-98	0.402	8.38	0.261	12.0	0.414	1.43	0.595	21.7
25-Aug-98	0.780	4.28	0.385	10.8	0.550	0.723	1.04	13.2

Grouped:	All Rivers	
Minimum	0.23	0.6
Maximum	1.04	42.1
Average	0.48	12.4
X_{95}	0.97	65.7
X_{50}	0.43	6.8
X_5	0.19	0.7

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-8
River Water Sampling for Selenium [Se] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**1.02**	1.02	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**
19-Aug-98	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**
25-Aug-98	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**	**1.02**

Grouped:	All Rivers	
Minimum	1.02	1.02
Maximum	1.02	1.02
Average	1.02	1.02
X_{95}	1.02	1.02
X_{50}	1.02	1.02
X_5	1.02	1.02

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Table III-9

Table III-9
River Water Sampling for Silver [Ag] (µg/L)

DATE	Eagle River		Knik River		Little Susititna River		Matanuska	
	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable	Dissolved	Total Recoverable
17-Aug-98	**0.0260**	0.0665	**0.0260**	0.0904	**0.0260**	0.0398	0.0563	0.169
19-Aug-98	**0.0260**	0.0527	**0.0260**	0.0626	**0.0260**	0.0317	**0.0260**	0.0991
25-Aug-98	**0.0260**	0.0528	**0.0260**	0.0654	**0.0260**	0.0364	**0.0260**	0.0591

Grouped:	All Rivers	
Minimum	0.0260	0.032
Maximum	0.0563	0.169
Average	0.0285	0.069
X_{95}	0.0400	0.132
X_{50}	0.0277	0.062
X_5	0.0192	0.029

NA = Not Applicable / Available

Bold = Value Below Detection Limit, Detection Limit Reported.

$X_{\#\#}$ = ## percentile based on a log normal distribution

Fish Tissue Levels of Mercury in Upper Cook Inlet

BATTELLE MARINE SCIENCE LABORATORIES
1529 West Sequim Bay Road
Sequim, Washington 98382-9099
360/681-3604

KINNETIC LABORATORIES
MERCURY IN TISSUE *(COHO SALMON)*
(Samples Received 8/19/98)

(CF#1253)

MSL Code	Sponsor ID	Percent Moisture	THg (µg/g dry wt.)	MeHg (µg/g dry wt.)
1253KL*15	MSR98MHG0001	72.2	0.210	0.175
1253KL*16 r1	MSR98MHG0002	73.6	0.197	0.165
1253KL*16 r2	MSR98MHG0002	73.6	0.209	0.169
1253KL*17	MSR98MHG0003	71.0	0.197	0.160
1253KL*18	MSR98MHG0004	72.3	0.173	0.140
1253KL*19	MSR98MHG0005	73.3	0.202	0.172
Blank			0.0731	0.00659
Detection Limit			0.0006	0.00353

STANDARD REFERENCE MATERIAL

DORM 2			4.45	3.66
	certified value		4.64	4.47
	range		±0.26	±0.32
	percent difference		4%	18%

MATRIX SPIKE RESULTS

Amount Spiked	4.99	2.09
1253KL*18	0.173	0.140
1253KL*18 MS	5.22	1.98
Amount Recovered	5.05	1.84
Percent Recovery	101%	88%

NOTE: Data is not blank corrected.

BATTELLE MARINE SCIENCE LABORATORIES

1529 West Sequim Bay Road
Sequim, Washington 98382-9099
360/681-3604

KINNETIC LABORATORIES
MERCURY IN TISSUE (SAFFRON COD)
(Samples Received 10/13/98)

(CF#1253)

MSL Code	Sponsor ID	Sample Date	Percent Moisture	THg (µg/g dry wt.)	MeHg (µg/g dry wt.)
			EPA Methods	245.6 modified	Bloom 1989
			Extraction Date:	10/20/98	10/19/98
			Analysis Date:	10/21/98	10/21/98
1253-82	MSR98MHG0010	10/9/98	80.8	0.206	0.186
1253-83r1	MSR98MHG0011	10/9/98	81.1	0.198	0.193
1253-83r2	MSR98MHG0011	10/9/98	81.1	0.199	NA
1253-84	MSR98MHG0012	10/9/98	80.8	0.277	0.230
1253-85r1	MSR98MHG0013	10/9/98	81.5	0.333	0.334
1253-85r2	MSR98MHG0013	10/9/98	81.5	NA	0.311
1253-86	MSR98MHG0014	10/9/98	81.0	0.396	0.398
Blank				0.0037	0.00559 U
Detection Limit				0.0006	0.00559

STANDARD REFERENCE MATERIAL

DORM 2				4.28	4.06
	certified value			4.64	4.47
	range			±0.26	±0.32
	percent difference			8%	9%
TORT 2				0.288	NA
	certified value			0.27	
	range			±0.06	
	percent difference			7%	NA
DOLT 2				NA	0.729
	certified value				0.693
	range				±0.0043
	percent difference			NA	5%

MATRIX SPIKE RESULTS

Amount Spiked				4.91	NS
1253-82	MSR98MHG0010	10/9/98		0.206	NS
1253-82 MS				5.10	NS
Amount Recovered				4.89	NS
Percent Recovery				100%	NS

QA/QC Officer	Date	Program Manager		Date

MATRIX SPIKE RESULTS

Amount Spiked				NS	1.93
1253-83	MSR98MHG0011	10/9/98		NS	0.193

BATTELLE MARINE SCIENCE LABORATORIES
1529 West Sequim Bay Road
Sequim, Washington 98382-9099
360/681-3604

KINNETIC LABORATORIES (SAFFRON COD)
MERCURY IN TISSUE
(Samples Received 10/13/98)

(CF#1253)

MSL Code	Sponsor ID	Sample Date	Percent Moisture	THg (µg/g dry wt.)	MeHg (µg/g dry wt.)
			EPA Methods	245.6 modified	Bloom 1989
			Extraction Date:	10/20/98	10/19/98
			Analysis Date:	10/21/98	10/21/98
1253-83 MS				NS	2.18
Amount Recovered				NS	1.99
Percent Recovery				NS	103%
REPLICATE ANALYSIS RESULTS					
1253-83r1	MSR98MHG0011	10/9/98	81.1	0.198	0.193
1253-83r2	MSR98MHG0011	10/9/98	81.1	0.199	NA
		RPD		1%	NA
1253-85r1	MSR98MHG0013	10/9/98	81.5	0.333	0.334
1253-85r2	MSR98MHG0013	10/9/98	81.5	NA	0.311
		RPD		NA	7%

NOTE: Data is not blank corrected.

U   Not detected at or above DL shown
NA Not available/applicable
NS Not spiked